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Date: **April 3, 1997**

Attached for filing is the patent application of:

Inventor: **Stephen D. Wolpe**

Irena Tsyrlova

Entitled: **INHIBITOR AND STIMULATOR OF STEM CELL PROLIFERATION AND USES THEREOF**

and including attachments as noted below:

[X] Declaration, [x] Abstract
[127] pages of specification and claims (including 88 numbered claims), and
[28] sheets of accompanying drawing/s.
[X] Record & return the attached assignment to the undersigned.
[ ] Priority is hereby claimed under 35 USC 119 based on the following foreign applications:

Application Number	Country	Day/Month/Year Filed

, respectively.
Certified copy(ies) of foreign application(s): [ ] attached; [ ] filed on _____
in U.S. Application Serial No. _____ filed on _____
or in PCT Application No. _____ filed _____

[X] Please amend the specification by inserting before the first line -- **This is a C-I-P of application Serial No. 08/627,173 filed April 3, 1996.** --

[ ] Priority is hereby claimed under 35 USC 120/365 based on the following prior PCT applications designating the U.S.:

Application Number	Country	Day/Month/Year Filed

[X] Verified Statement attached establishing "small entity" status (Rules 9 & 27).
[ ] Preliminary amendment to claims (attached hereto), to be entered before calculation of the fee below.
[ ] Also attached:

FILING FEE IS BASED ON CLAIMS AS FILED LESS ANY HEREWITH CANCELLED

Basic filing fee		$ 770.00
Total effective claims - 20 (at least 20) = 0 x $22		$ 0.00
Independent claims - 3 (at least 3) = 0 x $80		$ 0.00
If any proper multiple dependent claims now added for first time, add $260 (ignore improper)		$
SUBTOTAL		$ 770.00
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SECOND SUBTOTAL		$ 385.00
Assignment Recording Fee ($40.00)		$ 40.00
TOTAL FEE ENCLOSED		$ 425.00

The Commissioner is hereby authorized to charge any deficiency in the fee(s) filed, or asserted to be filed, or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our **Account No. 14-1140**. A duplicate copy of this sheet is attached.

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28 A 355—201 A

INHIBITOR AND STIMULATOR OF STEM CELL PROLIFERATION AND USES THEREOF

FIELD OF THE INVENTION

The present invention relates to the use of modulators of stem cell proliferation for regulating stem cell cycle in the treatment of humans or animals with autoimmune diseases, aging, cancer, myelodysplasia, preleukemia, leukemia, psoriasis, acquired immune deficiency syndrome (AIDS), myelodysplastic syndromes, aplastic anemia or other diseases involving hyper- or hypo-proliferative conditions, as well as the use of such compounds for analgesia. The present invention also relates to a method of treatment for humans or animals anticipating or having undergone exposure to chemotherapeutic agents, other agents which damage cycling stem cells, or radiation exposure and for protection against such agents during *ex vivo* treatments. Finally, the present invention relates to the improvement of stem cell maintenance or expansion cultures for auto- and allo-transplantation procedures or for gene transfer, as well as for *in vivo* treatments to improve such procedures.

BACKGROUND OF THE INVENTION

Most end-stage cells in renewing systems are short-lived and must be replaced continuously throughout life. For example, blood cells originate from a self-renewing population of multipotent hematopoietic stem cells (HSC). Hematopoietic stem cells are a subpopulation of hematopoietic cells. Hematopoietic cells can be obtained, for example, from bone marrow, umbilical cord blood or peripheral blood (either unmobilized or mobilized with an agent such as G-CSF); hematopoietic cells include the stem cell

population, progenitor cells, differentiated cells, accessory cells, stromal cells and other cells that contribute to the environment necessary for production of mature blood cells. Hematopoietic progenitor cells are a subset of stem cells which are more restricted in their developmental potency. Progenitor cells are able to differentiate into only one or two lineages (e.g., BFU-E and CFU-E which give rise only to erythrocytes or CFU-GM which give rise to granulocytes and macrophages) while stem cells (such as CFU-MIX or CFU-GEMM) can generate multiple lineages and/or other stem cells. Because the hematopoietic stem cells are necessary for the development of all of the mature cells of the hematopoietic and immune systems, their survival is essential in order to reestablish a fully functional host defense system in subjects treated with chemotherapy or other agents.

Hematopoietic cell production is regulated by a series of factors that stimulate growth and differentiation of hematopoietic cells, some of which, for example erythropoietin, GM-CSF and G-CSF, are currently used in clinical practice. One part of the control network which has not been extensively characterized, however, is the physiological mechanism that controls the cycling status of stem cells (Eaves *et al.* Blood 78:110-117, 1991; Lord, in Stem Cells (C.S. Potten, Ed.) pp 401-22, 1997 (Academic Press, NY)).

Early studies by Lord and coworkers showed the existence of soluble protein factors in normal and regenerating bone marrow extracts which could either inhibit or stimulate stem cell proliferation (reviewed in: Lord and Wright, Blood Cells 6:581-593, 1980; Wright and Lorimore, Cell Tissue Kinet. 20:191-203, 1987; Marshall and Lord, Int Rev. Cyt. 167:185-261, 1996). These activities were designated stem cell inhibitor (SCI) and stem cell stimulator (SCS), respectively.

To date, no candidate SCS molecules have been purified from bone marrow extracts prepared as described by Lord *et al.* (reviews referenced above). Purification of either SCS or SCI from primary sources was not accomplished due to the difficulties inherent in an *in vivo* assay requiring large numbers of irradiated mice. In an attempt to

overcome these problems Pragnell and co-workers developed an *in vitro* assay for primitive hematopoietic cells (CFU-A) and screened cell lines as a source of the inhibitory activity (see Graham *et al.* Nature 344:442-444, 1990). As earlier studies had identified macrophages as possible sources for SCI (Lord *et al.* Blood Cells 6:581-593, 1980), a mouse macrophage cell line, J774.2, was selected (Graham *et al.* Nature 344:442-444, 1990). The conditioned medium from this cell line was used by Graham *et al.* for purification; an inhibitory peptide was isolated which proved to be identical to the previously described cytokine macrophage inflammatory protein 1-alpha (MIP-1α). Receptors for MIP-1α have been cloned; like other chemokine receptors, these MIP-1α receptors are seven-transmembrane domain (or "G-linked") receptors which are coupled to guanine nucleotide (GTP) binding proteins of the Ginhibitory subclass ("G_i") (reviewed in Murphy, Cytokine & Growth Factor Rev. 7:47-64, 1996). The "inhibitory" designation for the G_i subclass refers to its inhibitory activity on adenylate cyclase.

MIP-1α was isolated from a cell line, not from primary material. While Graham *et al.* observed that antibody to MIP-1α abrogated the activity of a crude bone marrow extract, other workers have shown that other inhibitory activities are important. For example, Graham *et al.* (J. Exp. Med. 178:925-32, 1993) have suggested that TGFβ, not MIP-1α, is a primary inhibitor of hematopoietic stem cells. Further, Eaves *et al.* (PNAS 90:12015-19, 1993) have suggested that both MIP-1α and TGFβ are present at sub optimal levels in normal bone marrow and that inhibition requires a synergy between the two factors.

Recently, mice have been generated in which the MIP-1α gene has been deleted by homologous recombination (Cook *et al.*, Science 269:1583-5, 1995). Such mice have no obvious derangement of their hematopoietic system, calling into question the role of MIP-1α as a physiological regulator of stem cell cycling under normal homeostatic conditions. Similarly, although transforming growth factor beta (TGFβ) also has stem cell inhibitory activities, the long period of time it takes for stem cells to respond to this cytokine

suggests that it is not the endogenous factor present in bone marrow extracts; further, neutralizing antibodies to TGFβ do not abolish SCI activity in bone marrow supernatants (Hampson *et al.*, Exp. Hemat. 19:245-249, 1991).

Other workers have described additional stem cell inhibitory factors. Frindel and coworkers have isolated a tetrapeptide from fetal calf marrow and from liver extracts which has stem cell inhibitory activities (Lenfant *et al.*, PNAS 86:779-782, 1989). Paukovits *et al.* (Cancer Res. 50:328-332, 1990) have characterized a pentapeptide which, in its monomeric form, is an inhibitor and, in its dimeric form, is a stimulator of stem cell cycling. Other factors have also been claimed to be inhibitory in various *in vitro* systems (see Wright and Pragnell in Bailliere's Clinical Haematology v. 5, pp. 723-39, 1992 (Bailliere Tinadall, Paris); Marshall and Lord, Int Rev. Cyt. 167:185-261, 1996).

Tsyrlova *et al.*, SU 1561261 A1, disclosed a purification process for a stem cell proliferation inhibitor.

Commonly owned applications WO 94/22915 and WO96/10634 disclose an inhibitor of stem cell proliferation, and are hereby incorporated by reference in their entirety.

To date, none of these factors have been approved for clinical use. However, the need exists for effective stem cell inhibitors. The major toxicity associated with chemotherapy or radiation treatment is the destruction of normal proliferating cells which can result in bone marrow suppression or gastrointestinal toxicity. An effective stem cell inhibitor will protect these cells and allow for the optimization of these therapeutic regimens. Just as there is a proven need for a variety of stimulatory cytokines (i.e., cytokines such as IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-9, IL-11, IL-13, IL-14, IL-15, G-CSF, GM-CSF, erythropoietin, thrombopoietin, stem cell factor, flk2/flt3 ligand, etc., which stimulate the cycling of hematopoietic cells) depending upon the clinical situation, so too it is likely that a variety of inhibitory factors will be needed to address divergent clinical needs.

Further, there is a need to rapidly reverse the activity of such an inhibitor. The original studies of Lord *et al.* (reviews referenced above) demonstrated that the inhibitory activity could be reversed by addition of the stimulatory activity. While a variety of stem cell stimulatory cytokines has been identified (see above), none has been demonstrated to represent the activity described by Lord and coworkers as being present in bone marrow extracts and of being able to reverse the activity of the inhibitor.

Hematopoietic progenitors and stem cells primarily reside in the bone marrow in normal adults. Under certain conditions, for example chemotherapy or treatment with cytokines such as G-CSF, large numbers of progenitors and stem cells egress into the peripheral blood, a process referred to as "mobilization" (reviewed in Simmons *et al.*, Stem Cells 12 (suppl 1): 187-202, 1994; Scheding *et al.* Stem Cells 12 (suppl 1):203-11, 1994; Mangan, Sem. Oncology 22:202-9, 1995; Moolten, Sem. Oncology 22:271-90, 1995). Recent published data suggest that the vast majority of mobilized progenitors are not actively in cell cycle (Roberts and Metcalf, Blood 86:1600- ,1995; Donahue *et al.*, Blood 87:1644- , 1996; Siegert and Serke, Bone Marrow Trans. 17:467- 1996; Uchida *et al.*, Blood 89:465-72, 1997).

Hemoglobin is a highly conserved tetrameric protein with molecular weight of approximately 64,000 Daltons. It consists of two alpha and two beta chains. Each chain binds a single molecule of heme (ferroprotoporphyrin IX), an iron-containing prosthetic group. Vertebrate alpha and beta chains were probably derived from a single ancestral gene which duplicated and then diverged; the two chains retain a large degree of sequence identity both between themselves and between various vertebrates (see Fig. 16A). In humans, the alpha chain cluster on chromosome 16 contains two alpha genes ($alpha_1$ and $alpha_2$) which code for identical polypeptides, as well as genes coding for other alpha-like chains: zeta, theta and several non-transcribed pseudogenes (see Fig. 16B for cDNA and amino acid sequences of human alpha chain). The beta chain cluster on chromosome 11 consists of one beta chain gene and several beta-like genes: delta, epsilon,

G gamma and A gamma, as well as at least two unexpressed pseudogenes (see Fig. 16C for cDNA and amino acid sequences of human beta chain).

The expression of these genes varies during development. In human hematopoiesis, which has been extensively characterized, embryonic erythroblasts successively synthesize tetramers of two zeta chains and two epsilon chains (Gower I), two alpha chains and two epsilon chains (Gower II) or two zeta chains and two gamma chains (Hb Portland). As embryogenesis proceeds, the predominant form consists of fetal hemoglobin (Hb F) which is composed of two alpha chains and two gamma chains. Adult hemoglobin (two alpha and two beta chains) begins to be synthesized during the fetal period; at birth approximately 50% of hemoglobin is of the adult form and the transition is complete by about 6 months of age. The vast majority of hemoglobin (approximately 97%) in the adult is of the two alpha and two beta chain variety (Hb A) with small amounts of Hb F or of delta chain (Hb A_2) being detectable.

Several methods have been used to express recombinant hemoglobin chains in *E. coli* and in yeast (e.g., Jessen *et al.*, Methods Enz. 231:347-364, 1994; Looker *et al.*, Methods Enz. 231:364-374, 1994; Ogden *et al.*, Methods Enz. 231:374-390, 1994; Martin de Llano *et al.*, Methods Enz. 231:364-374, 1994). It has thus far not been possible to express isolated human alpha chain in high yields by recombinant methods (e.g., Hoffman *et al.*, PNAS 87:8521-25, 1990; Hernan *et al.*, Biochem. 31:8619-28, 1992). Apparently, the isolated alpha chain does not assume a stable conformation and is rapidly degraded in *E. coli*. Co-expression of beta chain with alpha chain results in increased expression of both (Hoffman *et al.* and Hernan *et al., op. cit.*). While the alpha chain has been expressed as a fusion protein with a portion of the beta chain and a factor Xa recognition site (Nagai and Thorgersen, Methods Enz. 231:347-364, 1994) it is expressed as an insoluble inclusion body under these conditions.

Both the beta chain and the alpha chain contain binding sites for haptoglobin. Haptoglobin is a serum protein with extremely high affinity for hemoglobin (e.g., Putnam

in The Plasma Proteins - Structure, Function and Genetic Control (F. W. Putnam, Ed.) Vol. 2, pp 1-49 (Academic Press, NY); Hwang and Greer, JBC 255:3038-3041, 1980). Haptoglobin transport to the liver is the major catabolic pathway for circulating hemoglobin. There is a single binding site for haptoglobin on the alpha chain (amino acids 121-127) and two on the beta chain (amino acid regions 11-25 and 131-146) (Kazim and Atassi, Biochem J. 197:507-510, 1981; McCormick and Atassi, J. Prot. Chem. 9:735-742, 1990).

Biologically active peptides with opiate activity have been obtained by proteolytic degradation of hemoglobin (reviewed in Karelin *et al.*, Peptides 16:693-697, 1995). Hemoglobin alpha chain has an acid-labile cleavage site between amino acids 94-95 (Shaeffer, J. Biol. Chem. 269:29530-29536, 1994).

Kregler *et al.* (Exp. Hemat. 9:11-21, 1981) have disclosed that hemoglobin has an enhancing activity on mouse bone marrow CFU-C progenitor colonies. Such assays demonstrate effects on CFU-GM and CFU-M progenitor populations as opposed to stem cells such as CFU-MIX. The authors observed activity in both isolated alpha and beta chains of hemoglobin. This activity was abolished by treatment with N-ethylmaleimide, which suggested to Kregler *et al.* that sulfhydryl groups were necessary. This observation, coupled with the fact that the stimulatory activity was resistant to trypsin digestion, suggested to Kregler *et al.* that the C-terminal hydrophobic domain or "core" region was responsible for the activity. Moqattash *et al.* (Acta. Haematol. 92:182-186, 1994) have disclosed that recombinant hemoglobin has a stimulatory effect on CFU-E, BFU-E and CFU-GM progenitor cell number which is similar to that observed with hemin. Mueller *et al.* (Blood 86:1974, 1995) have disclosed that purified adult hemoglobin stimulates erythroid progenitors in a manner similar to that of hemin.

Petrov *et al.* (Bioscience Reports 15:1-14, 1995) disclosed the use of a "nonidentified myelopeptide mixture" in the treatment of congenital anemia in the W^v/W^v

mouse. The mixture increased the number of spleen colonies, especially those of the erythroid type.

Heme and hemin have been extensively examined with regard to their influences on hematopoiesis (see S. Sassa, Seminars Hemat. 25:312-20, 1988 and N. Abraham *et al.*, Int. J. Cell Cloning 9:185-210, 1991 for reviews). Heme is required for the maturation of erythroblasts; in vitro, hemin (chloroferroprotoporphyrin IX - i.e., heme with an additional chloride ion) increases the proliferation of CFU-GEMM, BFU-E and CFU-E. Similarly, hemin increases cellularity in long-term bone marrow cultures.

"Opiates" are substances with analgesic properties similar to morphine, the major active substance in opium. Opiates can be small organic molecules, such as morphine and other alkaloids or synthetic compounds, or endogenous peptides such as enkephalins, endorphins, dynorphins and their synthetic derivatives. Endogenous opiate peptides are produced *in vivo* from larger precursors - pre-proenkephalin A for Met- and Leu-enkephalins, pre-proopiomelanocortin for α, β, and γ endorphins, and pre-prodynorphin for dynorphins A and B, α–neoendorphin and β–neoendorphin. In addition, peptides with opiate activity can be obtained from non-classical sources such as proteolysis or hydrolysis of proteins such as α or β casein, wheat gluten, lactalbumin, cytochromes or hemoglobin, or from other species such as frog skin (dermorphins) or bovine adrenal medulla. Such peptides have been termed "exorphins" in contrast to the classical endorphins; they are also referred to as atypical opiate peptides (Zioudrou *et al.*, JBC 254:2446-9, 1979; Quirion and Weiss, Peptides 4:445 , 1983; Loukas *et al.*, Biochem. 22:4567 , 1983; Brantl, Eur. J. Pharm. 106:213-14, 1984; Brantl *et al.*, Eur. J. Pharm. 111:293-4, 1985; Brantl *et al.*, Eur. J. Pharm. 125:309-10, 1986; Brantl and Neubert, TIPS 7:6-7,1986; Glamsta *et al.*, BBRC 184:1060-6, 1992; Teschemacher, Handbook Exp. Pharm. 104:499-28, 1993; Petrov *et al.*, Bioscience Reports 15:1-14, 1995; Karelin *et al.*, Peptides 16:693-7, 1995). Other endogenous peptides, such as the Tyr-MIF-1

family, have also been shown to have opiate activity (Reed *et al.*, Neurosci. and Biobehav. Rev. 18:519-25, 1994).

Opiates exert their actions by binding to three main pharmacological classes of endogenous opiate receptors - mu, delta, and kappa. Receptors representing each pharmacological class have been cloned and shown to be G-linked receptors coupled to G_i (reviewed in: Reisine and Bell, TINS 16: 506-510, 1993; Uhl *et al.*, TINS 17:89-93, 1994: Knapp *et al.*, FASEB J. 9:516-525, 1995; Satoh and Minami, Pharm. Ther. 68:343-64, 1995; Kieffer, Cell. Mol. Neurobiol. 15:615-635, 1995; Reisine, Neuropharm. 34:463-472, 1995; Zaki *et al.*, Ann. Rev. Pharm. Toxicol., 36:379-401, 1996).

Specific agonists and antagonists are available for each receptor type - e.g., for mu receptors (which are selectively activated by DAMGO and DALDA and selectively antagonized by CTOP and naloxonazine), for kappa receptors (which are selectively activated by GR 89696 fumarate or U-69593 and selectively antagonized by *nor* - binaltorphimine hydrochloride) and for delta receptors (which are selectively activated by DADLE and DPDPE and selectively antagonized by natrindole). In addition, there are broad-spectrum antagonists (such as naloxone) and agonists (such as etorphine) which act on all three receptor subtypes.

Both classical and atypical opiate peptides can be chemically altered or derivatized to change their specific opiate receptor binding properties (reviewed in Hruby and Gehrig, Med. Res. Rev. 9:343-401, 1989; Schiller, Prog. Med. Chem. 28: 301-40, 1991; Teschemacher, Handbook Exp. Pharm. 104:499-28, 1993; Handbook of Experimental Pharmacology, A. Hertz (Ed.) volumes 104/I and 104/II, 1993, Springer Verlag, Berlin; Karelin *et al.*, Peptides 16:693-7, 1995). Examples include derivatives of dermorphin (e.g., DALDA) and enkephalins (e.g., DADLE, DAMGO or DAMME). Peptides which do not normally bind to opiate receptors, such as somatostatin, can also be derivatized to exhibit specific opiate receptor binding (e.g., CTOP (Hawkins *et al.*, J.

Pharm. Exp. Ther. 248:73, 1989)). Analogs can also be derived from alkaloids such as morphine with altered receptor binding properties (e.g., heroin, codeine, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol and nalbuphine); in addition, small molecules structurally unrelated to morphine can also act on opiate receptors (e.g., meperidine and its congeners alphaprodine, diphenoxylate and fentanyl) (see Handbook of Experimental Pharmacology, *op. cit.*; Goodman and Gilman's The Pharmacological Basis of Therapeutics, 7th Ed., A. G. Gilman, L. S. Goodman, T. W. Rall and F. Murad (Eds.) 1985 Macmillan Publishing Co. NY).

The endogenous opiate peptides (enkephalins, endorphins and dynorphins) have a conserved N-terminal tetrapeptide Tyr-Gly-Gly-Phe, followed by Leu or Met and any remaining C-terminal sequence. Removal of the hydroxyl group on the N-terminal Tyr (resulting in an N-terminal Phe) results in a dramatic loss of activity for Met-enkephalin. These structural data led to the "message-address" hypothesis whereby the N-terminal "message" confers biological activity while the C-terminal "address" confers specificity and enhanced potency (Chavkin and Goldstein, PNAS 78:6543-7, 1981). Exorphins generally have a Tyr-Pro replacing the N-terminal Tyr-Gly of classical opiate peptides; the proline residue is thought to confer higher stability against aminopeptidase degradation (Shipp *et al.*, PNAS 86: 287- , 1989; Glamsta *et al.*, BBRC 184:1060-6, 1992).

Recently an orphan receptor ("ORL1") was cloned by virtue of sequence relatedness to the mu, delta and kappa opiate receptors (Mollereau *et al.*, FEBS 341:33-38, 1994; Fukuda *et al.*, FEBS 343:42-46, 1994; Bunzow *et al.*, FEBS 347:284-8, 1994; Chen *et al.*, FEBS 347:279-83, 1994; Wang *et al.*, FEBS 348:75-79, 1994; Keith *et al.*, Reg. Peptides 54 143-4, 1994; Wick *et al.*, Mol. Brain Res. 27: 37-44, 1994, Halford *et al.*, J. Neuroimmun. 59:91-101, 1995). The ligand for this receptor, variously called nociceptin or orphanin FQ (referred to hereafter as "nociceptin") has been cloned and shown to be a heptadecapeptide which is derived from a larger precursor (Meunier *et al.*,

Nature 377:532-535, 1995; Reinscheid *et al.*, Science 270:792-794, 1995). It was demonstrated to have pronociceptive, hyperalgesic functions *in vivo*, as opposed to classical opiates which have analgesic properties. Nociceptin has a Phe-Gly-Gly-Phe... N-terminal motif in contrast to the Tyr-Gly-Gly-Phe... N-terminal motif of classical opiate peptides discussed above. In keeping with the requirement for an N-terminal Tyr for opiate activity in classical opiate peptides, nociceptin exhibits little or no affinity for the mu, kappa or delta opiate receptors. Similarly, the broad-spectrum opiate antagonist naloxone has no appreciable affinity for ORL1.

Enkephalins have been observed to have effects on murine hematopoiesis *in vivo* under conditions of immobilization stress (Goldberg *et al.*, Folia Biol. (Praha) 36:319-331, 1990). Leu-enkephalin inhibited and met-enkephalin stimulated bone marrow hematopoiesis. These effects were indirect, Goldberg *et al.* believed, due to effects on glucocorticoid levels and T lymphocyte migration. Krizanac-Bengez *et al.* (Biomed. & Pharmacother. 46:367-43, 1992; Biomed. & Pharmacother. 49:27-31, 1995; Biomed. & Pharmacother. 50:85-91, 1996) looked at the effects of these compounds *in vitro*. Pre-treatment of murine bone marrow with Met- or Leu-enkephalin or naloxone affected the number of GM progenitor cells observed in a colony assay. This effect was highly variable and resulted in suppression, stimulation or no effect; further, there was no clear dose-response. This variability was ascribed by Krizanac-Bengez *et al.* to circadian rhythms and to accessory cells.

Recently, it has been demonstrated that mice in which the mu opiate receptor has been deleted by homologous recombination have elevated numbers of CFU-GM, BFU-E and CFU-GEMM per femur. Marrow and splenic progenitors were more rapidly cycling in these mu receptor knockout mice compared to normal mice. It was not determined if these effects were due to a direct or indirect effect on bone marrow stem cells resulting from the absence of the mu receptor in these animals (Broxmeyer *et al.*, Blood 88:338a, 1997).

I. Chemotherapy and Radiotherapy of Cancer

Productive research on stimulatory growth factors has resulted in the clinical use of a number of these factors (erythropoietin, G-CSF, GM-CSF, etc.). These factors have reduced the mortality and morbidity associated with chemotherapeutic and radiation treatments. Further clinical benefits to patients who are undergoing chemotherapy or radiation could be realized by an alternative strategy of blocking entrance of stem cells into cell cycle thereby protecting them from toxic side effects. The reversal of this protection will allow for rapid recovery of bone marrow function subsequent to chemo- or radiotherapy.

II. Bone Marrow and Stem Cell Transplantation, *Ex Vivo* Stem Cell Expansion and Tumor Purging

Bone marrow transplantation (BMT) is a useful treatment for a variety of hematological, autoimmune and malignant diseases. Current therapies include hematopoietic cells obtained from umbilical cord blood, fetal liver or from peripheral blood (either unmobilized or mobilized with agents such as G-CSF or cyclophosphamide) as well as from bone marrow; the stem cells may be unpurified, partially purified (e.g., affinity purification of the $CD34^+$ population) or highly purified (e.g., through fluorescent activated cell sorting using markers such as CD34, CD38 or rhodamine). *Ex vivo* manipulation of hematopoietic cells is currently being used to expand primitive stem cells to a population suitable for transplantation. Optimization of this procedure requires: (1) sufficient numbers of stem cells able to maintain long term reconstitution of hematopoiesis; (2) the depletion of graft versus host-inducing T-lymphocytes and (3) the absence of residual malignant cells. This procedure can be optimized by including a stem cell inhibitor(s) and/or a stem cell stimulator(s).

The effectiveness of purging of hematopoietic cells with cytotoxic drugs in order to eliminate residual malignant cells is limited due to the toxicity of these compounds for normal hematopoietic cells and especially stem cells. There is a need for effective protection of normal cells during purging; protection can be afforded by taking stem cells out of cycle with an effective inhibitor.

III. Peripheral Stem Cell Harvesting

Peripheral blood stem cells (PBSC) offer a number of potential advantages over bone marrow for autologous transplantation. Patients without suitable marrow harvest sites due to tumor involvement or previous radiotherapy can still undergo PBSC collections. The use of blood stem cells eliminates the need for general anesthesia and a surgical procedure in patients who would not tolerate this well. The apheresis technology necessary to collect blood cells is efficient and widely available at most major medical centers. The major limitations of the method are both the low normal steady state frequency of stem cells in peripheral blood and their high cycle status after mobilization procedures with drugs or growth factors (e.g., cyclophosphamide, G-CSF, stem cell factor). An effective stem cell inhibitor will be useful to return such cells to a quiescent state, thereby preventing their loss through differentiation.

IV. Treatment of Hyperproliferative Disorders

A number of diseases are characterized by a hyperproliferative state in which dysregulated stem cells give rise to an overproduction of end stage cells. Such disease states include, but are not restricted to, psoriasis, in which there is an overproduction of epidermal cells, premalignant conditions in the gastrointestinal tract characterized by the appearance of intestinal polyps, and acquired immune deficiency syndrome (AIDS) where early stem cells are not infected by HIV but cycle rapidly resulting in stem cell exhaustion. A stem cell inhibitor will be useful in the treatment of such conditions.

V. Treatment of Hypoproliferative Disorders

A number of diseases are characterized by a hypoproliferative state in which dysregulated stem cells give rise to an underproduction of end stage cells. Such disease states include myelodysplatic syndromes or aplastic anemia, in which there is an underproduction of blood cells, and conditions associated with aging where there is a deficiency in cellular regeneration and replacement. A stem cell stimulator will be useful in the treatment of such conditions.

VI. Gene Transfer

The ability to transfer genetic information into hematopoietic cells is currently being utilized in clinical settings. Hematopoietic cells are a useful target for gene therapy because of ease of access, extensive experience in manipulating and treating this tissue *ex vivo* and because of the ability of blood cells to permeate tissues. Furthermore, the correction of certain human genetic defects can be possible by the insertion of a functional gene into the primitive stem cells of the human hematopoietic system.

There are several limitations for the introduction of genes into human hematopoietic cells using either retrovirus vectors or physical techniques of gene transfer: (1) The low frequency of stem cells in hematopoietic tissues has necessitated the development of high efficiency gene transfer techniques; and (2) more rapidly cycling stem cells proved to be more susceptible to vector infection, but the increase of the infection frequency by stimulation of stem cell proliferation with growth factors produces negative effects on long term gene expression, because cells containing the transgenes are forced to differentiate irreversibly and lose their self-renewal. These problems can be ameliorated by the use of a stem cell inhibitor to prevent differentiation and loss of self-renewal and a stem cell stimulator to regulate the entry of stem cells into cycle and thereby facilitate retroviral-mediated gene transfer.

SUMMARY OF THE INVENTION

The present invention relates to compounds including peptides and polypeptides which are inhibitors and/or stimulators of stem cell proliferation (INPROL and opiate compounds) and their use.

The present invention includes an inhibitor of stem cell proliferation characterized by the following properties:

(a) Specific activity (IC_{50}) less than or equal to 20 ng/ml in a murine colony-forming spleen (CFU-S) assay (see Example 4),

(b) Molecular weight greater than 10,000 and less than 100,000 daltons (by ultrafiltration),

(c) Activity sensitive to degradation by trypsin,

(d) More hydrophobic than MIP-1α or TGFβ and separable from both by reverse phase chromatography (see Example 12),

(e) Biological activity retained after heating for one hour at 37°C, 55°C or 75°C in aqueous solution and

(f) Biological activity retained after precipitation with 1% hydrochloric acid in acetone.

The present invention is further characterized and distinguished from other candidate stem cell inhibitors (e.g., MIP-1α, TGFβ and various oligopeptides) by its capacity to achieve inhibition in an *in vitro* assay after a short preincubation period (see Example 5).

The present invention also comprises pharmaceutical compositions containing INPROL for treatment of a variety of disorders.

The present invention provides a method of treating a subject anticipating exposure to an agent capable of killing or damaging stem cells by administering to that subject an effective amount of a stem cell inhibitory composition. The stem cells protected by this method can be hematopoietic stem cells ordinarily present and dividing in the bone

marrow, cord blood, fetal liver or mobilized into the peripheral blood circulation. While the majority of mobilized stem cells are quiescent according to fluorescence activated cell sorter (FACS) analysis, the multipotential stem cells are demonstrated to be cycling and inhibitable by INPROL at stem cell inhibitory amounts. Alternatively, stem cells can be epithelial, located for example, in the intestines or scalp or other areas of the body or germ cells located in reproductive organs. The method of this invention can be desirably employed on humans, although animal treatment is also encompassed by this method. As used herein, the terms "subject" or "patient" refer to an animal, such as a mammal, including a human.

The present invention also provides a method of treating a subject with hypoproliferating stem cells by administering to that subject an effective amount of a stem cell stimulatory composition. The stem cells stimulated by this method can be hematopoietic stem cells ordinarily present in the bone marrow, cord blood, fetal liver or mobilized into the peripheral blood circulation; such stem cells may have previously been placed into quiescence by use of INPROL at stem cell inhibitory amounts. INPROL at stem cell stimulatory amounts will allow for stimulation of stem cell cycling when desired - for example, after harvesting of stem cells for use during *ex vivo* expansion, or *in vivo* subsequent to stem cell transplantation and engraftment. Alternatively, stem cells can be epithelial, located for example, in the intestines, or scalp or other areas of the body or germ cells located in reproductive organs.

In another aspect, the invention provides a method for protecting and restoring the hematopoietic, immune or other stem cell systems of a patient undergoing chemotherapy, which includes administering to the patient an effective stem cell inhibitory amount of INPROL and/or to stimulate recovery after chemotherapy or radiation by administering an effective stem cell stimulatory amount of INPROL.

In still a further aspect, the present invention involves a method for adjunctively treating any cancer, including those characterized by solid tumors (e.g., breast, colon,

lung, testicular, ovarian, liver, kidney, pancreas, brain, sarcoma), by administering to a patient having cancer an effective stem cell inhibitory amount of INPROL to protect stem cells of the bone marrow, gastrointestinal tract or other organs from the toxic effects of chemotherapy or radiation therapy and/or to stimulate recovery after chemotherapy or radiation therapy by administering stem cell stimulatory amounts of INPROL.

Yet another aspect of the present invention involves the treatment of leukemia (e.g., chronic myelogenous leukemia, acute myelogenous leukemia, chronic lymphocytic leukemia, acute lymphocytic leukemia, myeloma, Hodgkin's disease), comprising treating hematopoietic cells having proliferating leukemia cells therein with an effective amount of INPROL to inhibit proliferation of normal stem cells, and treating the bone marrow with a cytotoxic agent to destroy leukemia cells. This method can be enhanced by the follow-up treatment of the bone marrow with other agents that stimulate its proliferation; e.g., colony stimulating factors and/or INPROL at stem cell stimulatory amounts. In one embodiment this method is performed *in vivo*. Alternatively, this method is also useful for *ex vivo* purging and expansion of hematopoietic cells for transplantation.

In still a further aspect, the method involves treating a subject having any disorder caused by proliferating stem cells. Such disorders, such as psoriasis, myelodysplasia, some autoimmune diseases, immuno-depression in aging, myelodysplastic syndrome, aplastic anemia or stem cell exhaustion in AIDS are treated by administering to the subject an effective amount of INPROL to inhibit or to stimulate proliferation of the stem cell in question.

The present invention provides a method for reversibly protecting stem cells from damage from a cytotoxic agent capable of killing or damaging stem cells. The method involves administering to a subject anticipating exposure to such an agent an effective stem cell inhibitory amount of INPROL.

The present invention also provides a method for reversibly stimulating the proliferation of stem cells during the recovery phase after chemotherapy or radiation. The

method involves administering to a subject anticipating exposure to such an agent, an effective stem cell stimulatory amount of INPROL.

The present invention also provides:

An inhibitor of stem cell proliferation isolated from porcine or other bone marrow by the following procedure (see Example 12):

(a) Extraction of bone marrow and removal of particulate matter through filtration,

(b) Heat treatment at 56°C for 40 minutes followed by cooling in ice bath,

(c) Removal of precipitate by centrifugation at 10,000 g for 30 minutes at 4°C,

(d) Acid precipitation by addition of supernatant to 10 volumes of stirred ice-cold acetone containing 1% by volume concentrated hydrochloric acid and incubation at 4°C for 16 hours,

(e) Isolation of precipitate by centrifugation at 20,000 g for 30 minutes at 4°C and washing with cold acetone followed by drying,

(f) Isolation by reverse phase chromatography and monitoring activity by inhibition of colony formation by bone marrow cells pretreated with 5-fluorouracil and incubated in the presence of murine IL-3, as well as by absorption at 280 nm and by SDS-PAGE.

The present invention also provides:

A method for purifying an inhibitor of stem cell proliferation substantially free from other proteinaceous materials comprising the preceding steps, as also described in more detail below.

The present invention also provides:

A method of treatment for humans or animals wherein an inhibitor of stem cell proliferation functions to ameliorate immunosuppression caused by stem cell hyperproliferation.

The present invention also provides:

A method of treatment for humans or animals wherein INPROL at stem cell stimulatory amounts ameliorates bone marrow suppression caused by stem cell hypoproliferation.

The present invention also provides:

A method of treatment for humans or animals wherein said inhibitor of stem cell proliferation is administered after the stem cells are induced to proliferate by exposure to a cytotoxic drug or irradiation procedure. Stem cells are normally quiescent but are stimulated to enter cell cycle after chemotherapy. This renders them more sensitive to a second administration of chemotherapy; the current method protects them from this treatment.

The present invention also provides:

A method of treatment for humans or animals wherein a stimulator of stem cell proliferation (e.g., INPROL at stem cell stimulatory amounts) is administered, before or after INPROL at stem cell inhibitory amounts, to promote bone marrow regeneration. Stem cell inhibitory amounts of INPROL slow the rate at which stem cells transit the cell cycle and protect against chemotherapy or radiation; stem cell stimulatory amounts of INPROL reverse this inhibition and promote bone marrow recovery. Conversely, stem cell stimulatory amounts of INPROL can be used to promote bone marrow recovery while stem cell inhibitory amounts are used subsequently to return stem cells to quiescence once bone marrow recovery is achieved.

The present invention also provides:

A method of treatment for humans or animals wherein said inhibitor of stem cell proliferation is administered as an adjuvant before or together with vaccination for the purpose of increasing immune response.

The present invention also provides:

A method of treating immune deficiency in a mammal comprising administering to said mammal an immunostimulatory amount of INPROL.

The present invention also provides:

A method of treating pain in a mammal comprising administering to said mammal an analgesia-inducing amount of INPROL.

The present invention also provides:

A method of treatment for humans or animals receiving cytotoxic drugs or radiation treatment which comprises administering an effective amount of the inhibitor of stem cell proliferation to protect stem cells against damage.

The present invention also provides:

A method of treatment for humans or animals receiving cytotoxic drugs or radiation treatment which comprises administering an effective stem cell stimulatory amount of INPROL to enhance recovery after treatment.

The invention also includes a pharmaceutical composition comprising hemoglobin and a pharmaceutically acceptible carrier.

The invention also includes a pharmaceutical composition comprising (a) a polypeptide selected from the group consisting of the alpha chain of hemoglobin, the beta chain of hemoglobin, the gamma chain of hemoglobin, the delta chain of hemoglobin, the epsilon chain of hemoglobin and the zeta chain of hemoglobin, the polypeptide comprising amino acids 1-97 of the human alpha hemoglobin chain ("peptide 1-97") and the polypeptide comprising amino acids 1-94 of the human alpha hemoglobin chain ("peptide 1-94") and (b) a pharmaceutically acceptible carrier. Such pharmaceutical compositions be

can composed of a single polypeptide selected from said group, a mixture of polypeptides selected from said group or polypeptides from said group in the form of dimers or multimers, with or without heme.

The invention also includes peptides having the sequences:

Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val ("Peptide 43-55"),

Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys

where the two Cys residues form a disulfide bond ("Cyclic Peptide 43-55"),

Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys

where the two Cys residues are joined by a carbon bridge,

Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala ("Peptide 64-82"), and

a peptide comprising the first 97 N-terminal amino acids of human alpha hemoglobin as in Fig. 16A.

Also included in the invention are proteins and peptide sequences consisting of modified versions of the human alpha chain which retain stem cell inhibitory and/or stimulatory properties. Such modifications include, but are not limited to, removal or modification of the C-terminal hydrophobic domain (resulting in improved solubility characteristics) and/or removal or modification of the haptoglobin binding domain (resulting in improved pharmacokinetic properties). The C-terminal hydrophobic domain in human alpha hemoglobin is comprised of the region from amino acids 98 (phenylalanine) to 141 (arginine) and contains 23 hydrophobic amino acids out of a total of 44. The entire domain or one or more of these hydrophobic amino acids (6 alanines, 4 valines, 8 leucines, 2 proline and 3 phenylalanines) can be removed by deletion ("deleted" C-terminal hydrophobic domain). Alternatively, one or more of these amino acids can be substituted with a non-polar amino acid (e.g., glycine, serine, threonine, cysteine, tyrosine, asparagine or glutamine) ("substituted" C-terminal hydrophobic domain).

In another embodiment, chemical modifications such as carboxymethylation, which decrease the hydrophobic character of this region and increases solubility, is used.

In another embodiment, hydrophobic residues are substituted with the corresponding hydrophilic regions in the human beta hemoglobin sequence. For example, in the human beta hemoglobin sequence, the region between amino acids 107 (glycine) to 117 (histidine) or the region between amino acids 130 (tyrosine) to 139 (asparagine) are each relatively hydrophilic and each or both can be substituted for the equivalent hydrophobic regions in human alpha hemoglobin.

The haptoglobin binding domain is contained within the C-terminal hydrophobic region and is comprised of amino acids 121-127. This region can be removed by deletion in its entirety or one or more amino acids in this region can be deleted ("deleted" C-terminal haptoglobin binding domain). This region or one or more amino acids in this region can be substituted with other amino acids such as, for example, poly-alanine or poly-glycine or other amino acids which have the effect of abolishing the binding of the polypeptide to haptoglobin but maintain the stem cell inhibitory activity ("substituted" C-terminal haptoglobin binding domain).

Other embodiments of the invention encompass corresponding modifications to the beta hemoglobin chain (either in the C-terminal hydrophobic region and/or in one or both haptoglobin binding domains (amino acids 11-25 and 136-146)), and corresponding modifications to the delta, gamma, epsilon and/or zeta hemoglobin chains.

Also included in the invention are DNA sequences encoding the above identified peptides, vectors containing said DNA sequences and host cells containing said vectors. These peptides can be synthesized using standard chemical techniques (e.g., solid phase synthesis) or by using recombinant techniques (including fusion systems such as those employing glutathione-S-transferase (D.B.Smith and K.S. Johnson, Gene 67:31-40, 1988), thioredoxin (LaVallie *et al.*, Biotechnology 11:187-193, 1993) or ubiquitin (Butt *et al.*, PNAS 86:2540-4, 1989; Cherney *et al.*, Biochem. 30:10420-7, 1991; Baker *et al.*,

JBC 269:25381-6, 1994; US Patents 5,132,213; 5,196,321 and 5,391,490 and PCT WO 91/17245). Each of these articles, applications and patents is hereby incorporated by reference.

Additionally the invention includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with a compound capable of binding opiate receptors, advantageously the mu subclass of opiate receptors. Additionally the invention includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with a compound capable of binding nociceptin receptors (e.g., ORL1). Further, the invention includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with a compound capable of binding "opiate-like" receptors.

Peptides (called "hemorphins") have been isolated from hemoglobin which exhibit opiate activities (e.g., Brantl *et al.*, Eur. J. Pharm, 125:309-10, 1986; Davis *et al.* Peptides 10:747-51, 1989; Hoffman *et al.*, PNAS 87:8521-25, 1990; Hernan *et al.*, Biochem. 31:8619-28, 1992; Karelin *et al.* Bioch. Biophys. Res. Comm, 202:410-5, 1994; Zhao *et al.*, Ann. N.Y. Acad. Science 750:452-8, 1995; Petrov *et al.*, Bioscience Reports, 15:1-14, 1995; Karelin *et al.*, Peptides 16:693-697, 1995). Each of these articles is hereby incorporated by reference. Other atypical opiate peptides and small molecules also exist (Zioudrou *et al.*, JBC 254:2446-9, 1979; Quirion and Weiss, Peptides 4:445 , 1983; Loukas *et al.*, Biochem. 22:4567 , 1983; Brantl, Eur. J. Pharm. 106:213-14, 1984; Brantl *et al.*, Eur. J. Pharm. 111:293-4, 1985; Brantl and Neubert, TIPS 7:6-7,1986; Hruby and Gehrig, Med. Res. Rev. 9:343-401, 1989; Schiller, Prog. Med. Chem. 28: 301-40, 1991; Glamsta *et al.*, BBRC 184:1060-6, 1992; Teschemacher, Handbook Exp. Pharm. 104:499-28, 1993; Handbook of Experimental Pharmacology, A. Hertz (Ed.) volumes 104/I and 104/II, 1993, Springer Verlag, Berlin; Reed *et al.*, Neurosci. and Biobehav. Rev. 18:519-25, 1994; Karelin *et al.*, Peptides 16:693-7, 1995). Each of these articles is hereby incorporated by reference. As used herein, "opiate-like

receptors" are defined by their ability to bind opiates, INPROL, hemorphins, exorphins, nociceptin, Tyr-MIF-1 family members, alkaloids and/or other compounds which either inhibit or stimulate stem cell proliferation in a manner antagonized by the inclusion of an appropriate amount of naloxone (see Examples 29 and 38).

In addition, the invention includes a method of identifying receptor(s) and ligands comprising using INPROL (advantageously peptide forms such as Peptide 1-94, 1-97, 43-55 or 64-82) in a receptor binding assay. Further, the invention includes a method of identifying receptor(s) and ligands comprising using INPROL in an adenylate cyclase assay.

Additionally the invention includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with a compound (for example, mastoparan) capable of activating GTP-binding proteins, advantageously those of the Ginhibitory subtype.

The invention also includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with a peptide selected from the group of hemorphin peptides having the sequence:

Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln-Arg-Phe,

Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln-Arg,

Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln,

Leu-Val-Val-Tyr-Pro-Trp-Thr,

Leu-Val-Val-Tyr-Pro-Trp,

Leu-Val-Val-Tyr-Pro,

Val-Val-Tyr-Pro-Trp-Thr-Gln,

Tyr-Pro-Trp-Thr-Gln-Arg-Phe,

Tyr-Pro-Trp-Thr-Gln-Arg,

Tyr-Pro-Trp-Thr-Gln, and

Tyr-Pro-Trp-Thr.

The above peptides have sequence similarity and/or biological activity similar to other atypical opiate peptides such as those of the Tyr-MIF-1 family (see Reed *et al.*, Neurosci. Biobehav. Rev. 18:519-25, 1994 for review), the casein-derived casomorphins (Brantl *et al.*, Hoppe-Seyler's Z. Physiol. Chem. 360:1211-16, 1979; Loukas *et al.*, Biochem. 22:4567-4573, 1983; Fiat and Jolles, Mol. Cell. Biochem. 87:5-30, 1989), peptides derived from cytochrome b, termed cytochrophins (Brantl *et al.*, Eur. J. Pharm. 111:293-4, 1985), various exorphins and opiate peptides from human and non-human species (Zioudrou *et al.*, JBC 254:2446-9, 1979; Brantl, Eur. J. Pharm. 106:213-14, 1984; Brantl *et al.*, Eur. J. Pharm. 125:309-10, 1986; Brantl and Neubert, TIPS 7:6-7,1986; Glamsta *et al.*, BBRC 184:1060-6, 1992; Teschemacher, Handbook Exp. Pharm. 104:499-28, 1993; Karelin *et al.*, Peptides 16:693-7, 1995) as well as to peptides derived from combinatorial libraries screened for binding to opiate receptors (see Dooley *et al.*, Peptide Research 8:124-137, 1995 for review). Each of these articles is hereby incorporated by reference.

The invention also includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with a peptide selected from the group consisting of Tyr-MIF-1 related peptides, casomorphins, cytochrophins and exorphins. Specifically included are the Tyr-MIF-1 peptides having the sequences:

Tyr-Pro-Try-Gly-NH_2,

Tyr-Pro-Lys-Gly-NH_2,

Tyr-Pro-Leu-Gly-NH_2, and

Pro-Leu-Gly-NH_2.

The invention also includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with an opiate peptide selected from the group consisting of

(D-Ala^2,N-Me-Phe^4,Gly-ol^5)-Enkephalin (DAMGO),

(D-Arg^2,Lys^4)-Dermorphin-(1-4)-amide (DALDA),

(Phe^4)-Dermorphine (1-4) amide

Ac-Arg-Phe-Met-Trp-Met-Arg-NH_2,

Ac-Arg-Phe-Met-Trp-Met-Lys-NH_2, and

H-Tyr-Gly-Gly-Phe-Met-Arg-Arg-Val-NH_2.

The invention also includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with an opiate agonist compound selected from the group consisting of morphine, codeine, methadone, heroin, meperidine, alphaprodine, diphenoxylate, fentanyl, sufentanil, alfentanil, levorphanol, hydrocodone, dihydrocodeine, oxycodone, hydromorphone, propoxyphene, buprenorphine, etorphine, oxymorphone dextopropoxyphene, and meptazinol. Specifically included is morphine at inhibitory amounts less than 10^{-7} molar.

The invention also includes a method of inhibiting or stimulating stem cell proliferation comprising contacting hematopoietic cells with an opiate antagonist or mixed agonist/antagonist selected from the group consisting of naloxone, naltrexone, nalorphine, pentazocine, nalbuphine and butorphanol. Specifically included is naloxone at inhibitory amounts of less than 10^{-8} molar.

The invention also includes a method of stimulating stem cell proliferation comprising contacting hematopoietic cells with a stem cell stimulating amount of protein or peptide selected from the group that includes INPROL, myoglobin, DAMGO and DALDA.

The invention also includes a method of conducting gene therapy in a mammal comprising:

a) removing hematopoietic cells from said mammal,

b) treating said hematopoietic cells *ex vivo* with a stem cell stimulatory amount of INPROL and/or an opiate compound,

c) transfecting or infecting said hematopoietic cells with a predetermined gene,

d) contacting said transfected hematopoietic cells *ex vivo* with a stem cell inhibitory amount of INPROL and/or an opiate compound,

e) transplanting into said mammal the hematopoietic cells of step d

f) optionally treating said mammal *in vivo* with a stem cell inhibitory or stimulatory quantity INPROL and/or an opiate compound.

The invention also includes a method of conducting *ex vivo* stem cell expansion comprising treating said hematopoietic cells with stem cell inhibitory amounts of INPROL and at least one stimulatory cytokine. INPROL is contacted with the hematopoietic cells before, during and/or after contact with the stimulatory cytokine. *Ex vivo* stem cell expansion allows the production of sufficient amounts of stem cells from limiting sources such as cord blood, fetal liver, autologous bone marrow after chemotherapy, etc. or after purification (e.g., through fluorescent activated cell sorting using markers such as CD34, CD38 or rhodamine). The ability to selectively grow particular hematopoietic lineages also allows the clinician to specifically design stem cell transplants according to the needs of an individual patient.

The invention also includes a method of conducting *ex vivo* stem cell expansion comprising treating hematopoietic cells with stem cell stimulatory amounts of INPROL with or without at least one additional stimulatory cytokine. INPROL is contacted with the hematopoietic cells before, during and/or after contact with the stimulatory cytokine(s). *Ex vivo*, a stem cell stimulator will allow for expansion of stem cells and/or progenitors while a stem cell inhibitor will maintain stem cells in their undifferentiated state. The procedure can also be optimized by the use of INPROL at stem cell inhibitory amounts *in vivo* to maintain stem cells in a quiescent state until they are engrafted, after which INPROL at stem cell stimulatory amounts can be used to stimulate bone marrow regeneration. Optionally, the hematopoietic cells may be split into two preparations and one treated with stem cell stimulatory amounts of INPROL to promote expansion of stem cells and/or progenitors while the other is treated with stem cell inhibitory amounts of

INPROL to maintain stem cells in their undifferentiated state. The two preparations can then be combined and infused into a patient.

The invention also includes a pharmaceutical composition comprising (a) INPROL and (b) at least one inhibitory compound selected from the group consisting of MIP-1α, TGFβ, TNFα, INFα, INFβ, INFγ, the pentapeptide pyroGlu-Glu-Asp-Cys-Lys, the tetrapeptide N-Acetyl-Ser-Asp-Lys-Pro, and the tripeptide glutathione (Gly-Cys-γGlu).

The invention also includes a pharmaceutical composition comprising (a) INPROL and (b) at least one stimulatory cytokine selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-9, IL-11, IL-13, IL-14, IL-15, G-CSF, GM-CSF, M-CSF, erythropoietin, thrombopoietin, stem cell factor, delta-like protein and flk2/flt3 ligand.

The current invention describes an inhibitor of stem cells (INPROL) which is different from those known in the art such as MIP-1α, TGFβ, the tetrapeptide of Frindel and colleagues or the pentapeptide of Paukovits and coworkers (cf., Wright & Pragnell, 1992 (*op. cit.*)). Naturally occuring native INPROL has a molecular weight exceeding 10,000 daltons by ultrafiltration which distinguishes it from the tetrapeptide as well as the pentapeptide. It is more hydrophobic than MIP-1α or TGFβ in reverse phase chromatography systems, distinguishing it from those cytokines. Further, its mode of action is different from that of any previously described inhibitor in that it is active in an *in vitro* assay when used during a preincubation period only. MIP-1α for example, is not effective when used during a preincubation period only (Example 5). Further, naturally occuring INPROL is active in an assay measuring "high proliferative potential cells" (HPP-PFC) whereas MIP-1α is not (Example 6). INPROL is different from those stimulators known in the art such as IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IL-16, G-CSF, GM-CSF, M-CSF, erythropoietin, thrombopoietin, stem cell factor, and flk2/flt3 ligand. Naturally occuring INPROL has little or no sequence similarity to these cytokines.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1-4 show an SDS polyacrylamide gel run of the product after each stage of purification.

Figure 1 - Lane 1 is chymotrypsinogen, Lane 2 is ovalbumin, Lane 3 is BSA, Lane 4 is fractions <30 kD, Lane 5 is fractions 30-50 kD and Lane 6 is fractions 50-100 kD.

Figure 2 - Lane 1 is after ammonium sulfate precipitation (40-80%) and lanes 2-5 are DEAE fractions (Lane #2 represents the active fraction).

Figure 3 - Lane 1 is the supernatant after ammonium sulfate precipitation, Lane 2 is the active DEAE fraction, Lanes 3-5 represent gel filtration fractions (lane #5 represents the active fraction)

Figure 4 - Lane 2 represents the final product.

Figure 5 shows a reverse phase HPLC chromatogram of the final purification.

Figure 6 shows tritiated thymidine incorporation (cpm) into cells of the FDCP-mix line without (Control = 0% Inhibition) and with various amounts of INPROL purified from porcine bone marrow (pINPROL). Data are normalized against the control value.

Figure 7 shows the percent of cells in the S phase of the cell cycle after treatment of mice with testosterone propionate (TSP), TSP plus pINPROL, or vehicle (Control). Each group contained 25 animals (3-4 per time point).

Figure 8 shows survival of mice treated with two doses of 5-FU, with or without pINPROL treatment. Each group contained 30 animals.

Figure 9 shows survival of irradiated mice, with and without pINPROL treatment. Each group contained 50 animals.

Figures 10 A and 10 B show regeneration of normal bone marrow long term culture cells 1 week (10 A) and 3 weeks (10 B) after treatment with Ara-C or Ara-C plus pINPROL.

Figure 11 shows survival of mice (75 per group) after lethal irradiation and transplantation of $3x10^4$ bone marrow cells after pre-incubation with medium (Control) or pINPROL (25 ng/ml) for 4 hours. Survival was monitored for 30 days.

Figure 12 shows the CFU-GM number formed after 14 days in culture by bone marrow cells from mice after lethal irradiation and restoration with donor bone marrow cells preincubated with pINPROL or medium for 4 hours.

Figure 13 shows suspension cells from lymphoid long-term culture which were taken every week, washed out, and plated with IL-7 (10 ng/ml) after preincubation with medium or pINPROL for 4 hours.

Figure 14 shows improved repopulating ability of leukemic peripheral blood cells treated with pINPROL. Long term culture initiating cells (LTC-IC) were measured by plating adherent and nonadherent LTC cells with and without pINPROL, and scoring CFU-GM on day 7. Data are normalized to control values.

Figure 15A shows a C4 reverse phase chromatogram of purified pINPROL eluting at 53% acetonitrile. Lane 1 is the crude material, Lane 2 is molecular weight markers and Lane 3 is the purified material. Figure 15B shows a C4 reverse phase chromatogram of MIP-1α eluting at 43.9% acetonitrile. Figure 15C shows an SDS-PAGE chromatogram of the crude pINPROL preparation and of the purified preparation after reverse phase.

Figure 16 shows hemoglobin sequences: Fig. 16A shows the cDNA and amino acid sequences of human alpha hemoglobin and Fig. 16B shows the cDNA and amino acid sequences of human beta hemoglobin. Numbering is according to the amino acid. Fig. 16C shows an amino acid sequence comparison of the alpha and beta chains of human, murine and porcine hemoglobins.

Figure 17 shows a comparison of the C4 reverse-phase HPLC traces of pINPROL (Fig. 17A) and of crystallized pig hemoglobin (Fig. 17B).

Figure 18 shows an SDS-PAGE gel of fractions from a C4 reverse phase HPLC separation of crystallized pig hemoglobin. Lane 1 shows molecular weight markers, Lane 2 shows Fractions 48-49, derived from the first peak (at 47.11 min), Lane 3 shows fractions 50-51, derived from the second peak (at 49.153 min), Lane 4 shows fractions 54-55, derived from the third peak (at 52.25 min) and Lane 5 shows fractions 56-57, derived from the fourth peak (at 53.613 minutes).

Figure 19 shows a comparison of the 2-dimensional gel electrophoreses of pINPROL (Fig. 19A) and of purified pig beta hemoglobin (Fig. 19B).

Figure 20 shows a comparison of the effects of purified pig alpha hemoglobin, beta hemoglobin or pINPROL in the FDCP-MIX assay.

Figure 21 shows the reverse phase separation of porcine hemoglobin using a shallow elution gradient.

Figure 22A shows the plasmid from Hochuli *et al.*, (1988); Figure 22B shows the plasmid of Loetscher *et al.*, (1991); Figure 22C shows the pDSUb plasmid.

Figure 23 shows the results of treatment with INPROL on the cobblestone assay.

In order that the invention herein described may be more fully understood, the following detailed description is set forth. This description, while exemplary of the present invention, is not to be construed as specifically limiting the invention and such variations which would be within the purview of one skilled in this art are to be considered to fall within the scope of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

INPROL reversibly inhibits or stimulates division of stem cells. While not wishing to be bound to a specific theory, stem cell inhibitors and stimulators are thought to exert their effects by influencing the rate at which stem cells transit through the cell cycle. Specifically, INPROL is effective in temporarily inhibiting or stimulating cell division of hematopoietic stem cells depending on the amount used. The ability to use a compound clinically which can inhibit or stimulate stem cell proliferation allows for exquisite control of the cycling of hematopoietic stem cells during, for example, chemotherapy, stem cell transplantation or gene therapy protocols. Thus, the method of this invention can be employed in alleviating the undesirable side effects of chemotherapy on the patient's hematopoietic, myeloid and immune systems by protecting stem cells from damage caused by chemotherapeutic agents or radiation used to destroy cancer or virally infected cells or by stimulating recovery after such damage. In one embodiment of the invention, INPROL is administered to the patient in a dosage sufficient to inhibit stem cell division while the chemotherapeutic agent acts on diseased cells. After the chemotherapeutic agent has performed its function, the stem cells inhibited by INPROL will, without further treatment, revert to dividing cells. If it is desired to enhance the regeneration of hematopoiesis, stimulatory growth factors, cytokines or stem cell stimulatory amounts of INPROL can be used in addition.

As used herein, the term "INPROL" includes mammalian and non-mammalian proteins, purified as in the Examples, hemoglobin, the alpha chain of hemoglobin (with or without the heme group), the beta chain of hemoglobin (with or without the heme group), mixtures of alpha and beta chains (with or without the heme group), and fragments or analogs of these proteins including embryonic, fetal or adult forms (e.g., alpha, beta, gamma, delta, epsilon or zeta chains, either alone or as mixtures, dimers or multimers, with or without the heme group) having the ability to inhibit and/or stimulate stem cell proliferation. The term "INPROL" includes naturally occurring as well as non-naturally occurring (e.g., recombinantly and/or synthetically produced) forms of these proteins. The term "INPROL polypeptide" refers to INPROL consisting of 40 or more amino acids.

As used herein, the term "opiate compounds" are compounds, including opiates but not INPROL, which bind to opiate receptors (or to receptors bearing sequence relatedness to opiate receptors, e.g., ORL1) and exert either agonist, antagonist or mixed agonist/antagonist activities. For example, specific agonists and antagonists exist for mu receptors (which are selectively activated by DAMGO and DALDA and selectively antagonized by CTOP and naloxonazine), for kappa receptors (which are selectively activated by GR 89696 fumarate or U-69593 and selectively antagonized by *nor* - binaltorphimine hydrochloride) and for delta receptors (which are selectively activated by DADLE and DPDPE and selectively antagonized by natrindole). In addition, there are broad-spectrum antagonists (such as naloxone) and agonists (such as etorphine) which act on all three receptor subtypes. Nociceptin specifically agonizes the ORL1 receptor. Opiate compounds with stem cell stimulatory and/or inhibitory activities can be used for each of the applications described herein for INPROL.

As used herein, "stem cell stimulatory amount" is that amount which induces proliferation of stem cells. As used herein, "stem cell inhibitory amount" is that amount which inhibits proliferation of stem cells. In all cases, both *in vivo* and *ex vivo*, the amount selected will depend upon the specific INPROL or opiate compound selected and

the specific condition or application; in particular, equimolar doses of polypeptides or fragments of INPROL are active as are equimolar opiate peptides or small molecules.

In a typical clinical situation, where stem cell inhibition is desired, INPROL is administered to a patient in a daily regimen by intravenous injection or infusion in dosage unit form using, for example, 0.01 to 100 mg/kg, advantageously 0.1 to 1.0 mg/kg, of INPROL administered, e.g., 4 to 60 hours prior to standard chemotherapy or radiation treatments when it is desirable to inhibit stem cell cycling.

In situations where stimulation of stem cell cycling is desirable, such as to promote recovery after chemotherapy or radiation, INPROL at stem cell stimulatory amounts are used. Such doses are typically 1-500 mg/kg, advantageously 10 mg to 100 mg/kg.

In cases where it is desirable to use opiate compound(s) to inhibit or to stimulate stem cell cycling, the opiate compound(s) are used at equimolar concentrations to that described for INPROL.

In another embodiment of the invention, pretreatment with INPROL at stem cell inhibitory amounts allows for increased doses of chemotherapeutic agents or of radiation beyond doses normally tolerated in patients. Similarly, post-chemotherapy or post-radiation treatment with INPROL at stem cell stimulatory amounts also allows for increases in normally tolerated doses of chemotherapy or radiation.

A large fraction of hematopoietic stem cells are normally quiescent (slowly or non-cycling). However, as a compensatory response to chemotherapy-induced hematopoietic damage, a larger proportion of stem cells enter into cycling after chemotherapy, which makes them particularly vulnerable to subsequent doses of cytotoxic chemotherapy or therapeutic irradiation. By inhibiting cycling of such stem cells, INPROL treatment permits earlier or more frequent administration of subsequent doses of cytotoxic chemotherapy, either at conventional or elevated doses.

Some normal individuals have stem cells that spontaneously cycle rapidly; INPROL at stem cell inhibitory amounts is useful in such individuals even if given prior to the first dose of radiation or chemotherapy.

In one embodiment of the invention, INPROL (0.1 mgs. to 6 gms/kg body weight - advantageously 1.0 to 60 mgs./kg) is administered about 24 hours to 10 days after an initial dose of chemotherapy. After another 4 to 60 hours, advantageously 24 to 48 hours, another dose of chemotherapy is administered. This cycle of alternating chemotherapy and INPROL is continued according to therapeutic benefit. Chemotherapy agents and protocols for administration are selected according to suitability for particular tumor types in standard clinical practice. Optionally, stimulatory growth factors such as G-CSF, stem cell factor, or INPROL at stem cell stimulatory amounts is used after chemotherapy or radiation treatment to further improve hematopoietic reconstitution.

For *ex vivo* applications 0.1 ng to 100 ng/10^6 cells/ml, advantageously 2-50 ng/10^6 cells/ml, of INPROL are used in cases where inhibition of stem cell proliferation is desired. For cases where stem cell stimulation is desired, 10 ng - 100 µg/10^6 cells/ml, advantageously 1-100 µg/10^6 cells/ml, of INPROL are used.

In cases where it is desirable to use opiate compound(s)to inhibit or stimulate stem cell cycling, the opiate compound(s) are used at equimolar concentrations to that described for INPROL.

In another embodiment of the invention, INPROL is employed in a method for preparing autologous hematopoietic cells for transplantation. The hematopoietic cells are treated *ex vivo* with an effective amount of INPROL to inhibit stem cell division and then purged of cancerous cells by administering to the marrow cultures an effective amount of a chemotherapeutic agent or radiation. Chemotherapy agents with specificity for cycling cells are preferred. Marrow thus treated is reinjected into the autologous donor. Optionally, the patient is treated with stem cell stimulatory amounts of INPROL and/or another agent known to stimulate hematopoiesis to improve the hematopoietic

reconstitution of the patient. Such a technique allows for effective purging of tumor cells during autologous bone marrow grafts while protecting hematopoietic stem cells. Such protection can be afforded with either *ex vivo* or *in vivo* purging protocols. Once successfully transplanted, there is a need for stem cells to rapidly proliferate to regenerate normal bone marrow function. This can be afforded by the use of INPROL at stem cell stimulatory amounts which stimulates cycling of stem cells and enhances recovery of bone marrow function.

In another embodiment of the invention, INPROL is employed in a method for preparing hematopoietic cells for gene therapy. The hematopoietic cells are treated *ex vivo* with INPROL at stem cell stimulatory amounts and/or other stimulatory cytokine(s) to stimulate stem cell division, and then transfected (advantageously infected using e.g. a retroviral vector) with the gene(s) of interest. After transfection has been achieved, cells are washed and treated with INPROL at stem cell inhibitory amounts to return stem cells to quiescence. Marrow thus treated is reinjected into the donor. Optionally, the patient is treated *in vivo* with INPROL at stem cell inhibitory amounts to maintain stem cells in their quiescent form and to increase their marrow repopulating ability.

In another embodiment of the invention, INPROL is employed as an adjunctive therapy in the treatment of leukemia. For example, in disease states where the leukemic cells do not respond to INPROL, the hematopoietic cells are treated *ex vivo* with INPROL at stem cell inhibitory amounts. The proliferation of normal stem cells is prevented by administration of INPROL. Thus, during the time that the proliferating leukemic cells are treated with a cell cycle-specific cytotoxic agent, a population of normal stem cells is protected from damage. Additionally, a stimulatory cytokine, such as IL-3, GM-CSF, is optionally administered to induce cycling in the leukemic cells during drug or radiation treatment while the normal stem cells are protected with INPROL. The patient is treated with chemotherapy agents or radiation to destroy leukemic cells, and the purged marrow is then transplanted back into the patient to establish hematopoietic reconstitution.

Similarly, in another embodiment of the invention for treatment of patients with serious viral infections that involve blood cells or lymphocytes, such as HIV infection, hematopoietic cells are treated *ex vivo* or *in vivo* with INPROL followed by antiviral agents, drugs which destroy infected cells, or antibody-based systems for removing infected cells. Following myeloablative antiviral or myeloablative chemotherapy to eradicate viral host cells from the patient, the INPROL-treated marrow cells are returned to the patient.

In another embodiment of the invention, INPROL is employed to treat disorders related to hyperproliferative stem cells. For example, psoriasis is a disorder caused by hyperproliferating epithelial cells of the skin and is sometimes treated with cytotoxic drugs. Other pre-neoplastic lesions in which stem cell proliferation is involved are also amenable to effective amounts of INPROL employed to inhibit the proliferation of the stem cells. Patients with acquired immune deficiency syndrome have abnormally high rates of stem cell cycling resulting in stem cell exhaustion; these patients also benefit from treatment with effective amounts of INPROL to inhibit stem cell cycling. For these uses, topical or transdermal delivery compositions (e.g., ointments, lotions, gels or patches) containing INPROL are employed where appropriate, as an alternative to parenteral administration.

In most cases of leukemia, the leukemia progenitors are differentiated cell populations which are not affected by INPROL and which are therefore treated by methods using INPROL such as those described above. In cases where leukemia progenitors are very primitive and are directly sensitive to inhibition by INPROL, proliferation of leukemia cells is attenuated by administration of effective amounts of INPROL.

In another embodiment of the invention, INPROL is employed to treat disorders related to hypoproliferative stem cells. For example, myelodysplasic syndromes and aplastic anemia are disorders caused by hypoproliferating stem cells of the bone marrow.

Other syndromes in which stem cell hypoproliferation is involved are treatable with stem cell stimulating amounts of INPROL.

Antibodies, monoclonal or polyclonal, are developed by standard techniques to the INPROL peptides or polypeptides. These antibodies or INPROL peptides or polypeptides are labeled with detectable labels of which many types are known in the art. The labeled INPROL or anti-INPROL antibodies are then employed as stem cell markers to identify and isolate stem cells by administering them to a patient directly for diagnostic purposes. Alternatively, these labeled peptides, polypeptides or antibodies are employed *ex vivo* to identify stem cells in a hematopoietic cell preparation to enable their removal prior to purging neoplastic cells in the marrow. In a similar manner, such labeled peptides, polypeptides or antibodies are employed to isolate and identify epithelial or other stem cells. In addition, such antibodies, labeled or unlabeled, are used therapeutically through neutralization of INPROL activity or diagnostically through detection of circulating INPROL levels.

INPROL can be cloned from human gene or cDNA libraries for expression of recombinant human INPROL using standard techniques. For example, using sequence information obtained from the purified protein, oligonucleotide probes are constructed which can be labeled, e.g., with 32-phosphorus, and used to screen an appropriate cDNA library (e.g., from bone marrow). Alternatively, an expression library from an appropriate source (e.g., bone marrow) is screened for cDNA's coding for INPROL using antibody or using an appropriate functional assay (e.g., that described in Example 2). Hemoglobin itself, as well as the individual alpha and beta chains, have been cloned and expressed using methods known in the state of the art (see Pagnier *et al.*, Rev. Fr. Transfus. Hemobiol. 35:407-15, 1992; Looker *et al.*, Nature 356:258-60, 1992; Methods in Enzymology vol. 231, 1994).

The present invention includes DNA sequences which include: the incorporation of codons "preferred" for expression by selected nonmammalian hosts: the provision of sites

for cleavage by restriction endonuclease enzymes; and the provision of additional initial, terminal or intermediate DNA sequences which facilitate construction of readily-expressed vectors or production or purification of the alpha, beta, gamma, delta, epsilon and/or zeta chain of hemoglobin.

The present invention also provides DNA sequences coding for polypeptide analogs or derivatives of hemoglobin alpha, beta, gamma, delta, epsilon and/or zeta chains which differ from naturally-occurring forms in terms of the identity or location of one or more amino acid residues (i.e., deletion analogs containing less than all of the residues specified; substitution analogs, wherein one or more residues specified are replaced by other residues; and addition analogs wherein one or more amino acid residues is added to a terminal or medial portion of the polypeptide) and which share some or all of the properties of naturally-occurring forms.

In an advantageous embodiment, INPROL is the product of prokaryotic or eukaryotic host expression (e.g., by bacterial, yeast, higher plant, insect and mammalian cells in culture) of exogenous DNA sequences obtained by genomic or cDNA cloning or by gene synthesis. That is, in an advantageous embodiment, INPROL is "recombinant INPROL". The product of expression in typical yeast (e.g., *Saccharomyces cerevisiae*) or prokaryote (e.g., *E. coli)* host cells are free of association with any mammalian proteins. The products of expression in vertebrate (e.g.,non-human mammalian (e.g., COS or CHO) and avian) cells are free of association with any human proteins. Depending upon the host employed, polypeptides of the invention can be glycosylated or can be non-glycosylated. Polypeptides of the invention optionally also include an initial methionine amino acid residue (at position -1).

The present invention also embraces other products such as polypeptide analogs of the alpha, beta, gamma, delta, epsilon and/or zeta chain of hemoglobin. Such analogs include fragments of the alpha, beta, gamma, delta, epsilon and/or zeta chain of hemoglobin. Following well known procedures, one can readily design and manufacture

genes coding for microbial expression of polypeptides having primary sequences which differ from that herein specified for in terms of the identity or location of one or more residues (e.g., substitutions, terminal and intermediate additions and deletions). Alternatively, modifications of cDNA and genomic genes can be readily accomplished by well-known site-directed mutagenesis techniques and employed to generate analogs and derivatives of the alpha, beta, gamma, delta, epsilon or zeta chains of hemoglobin. Such products share at least one of the biological properties of INPROL but can differ in others. As examples, products of the invention include the alpha, beta, gamma, delta, epsilon or zeta chains which is foreshortened by e.g., deletions; or those which are more stable to hydrolysis (and, therefore, can have more pronounced or longer-lasting effects than naturally-occurring); or which have been altered to delete or to add one or more potential sites for O-glycosylation and/or N-glycosylation or which have one or more cysteine residues deleted or replaced by, e.g., alanine or serine residues and are more easily isolated in active form from microbial systems; or which have one or more tyrosine residues replaced by phenylalanine and bind more or less readily to target proteins or to receptors on target cells. Also comprehended are peptide or polypeptide fragments duplicating only a part of the continuous amino acid sequence or secondary conformations within the alpha, beta, gamma, delta, epsilon or zeta chains which fragments can possess one property of INPROL (e.g., receptor binding) and not others (e.g., stem cell inhibitory activity). It is noteworthy that activity is not necessary for any one or more of the products of the invention to have therapeutic utility (see, Weiland *et al.*, Blut 44:173-5, 1982) or utility in other contexts, such as in assays of inhibitory factor antagonism. Competitive antagonists are useful in cases of overproduction of stem cell inhibitors or its receptor.

In addition, peptides derived from the protein sequence which retain biological activity can be chemically synthesized using standard methods. The present invention also provides for sequences coding for peptide analogs or derivatives of hemoglobin alpha,

beta, gamma, delta, epsilon and/or zeta chain which differ from naturally-occurring forms in terms of the identity or location of one or more amino acid residues (e.g., deletion analogs containing less than all of the residues specified; substitution analogs, wherein one or more residues specified are replaced by other residues, either naturally occuring or other analogs known in the state of the art such as D-amino acids; and addition analogs wherein one or more amino acid residues is chemically modified to increase stability, solubility and/or resistance to proteolysis) and which share some or all of the properties of naturally-occurring forms.

Peptide sequences such as described above can be identified by a variety of means. Comparison of the three dimensional structures of native hemoglobin chains active in the assay (e.g., alpha chain) with structurally related proteins which are inactive (e.g., myoglobin) can identify regions which have different conformations in three-dimensional space and which are therefore candidate regions for active peptides. Another approach uses selective proteolysis, in which proteolytic enzymes are used in limited digests of hemoglobin chains resulting in peptides which can separated, for example, by reverse phase HPLC and then assayed for stem cell inhibition. Peptides can also be generated by chemical synthesis (e.g., solid phase synthesis); a series of overlapping peptides (e.g., 15-mers) which encompass the sequence of the hemoglobin chain of interest (e.g., alpha chain) can easily be generated and tested in stem cell assays. Combinatorial libraries can be generated in which multiple chemical syntheses are conducted and where selected amino acid positions are made variable resulting in large numbers of peptide analogs for screening (e.g., Dooley *et al.*, Peptide Research 8:124-137, 1995). Alternatively, recombinant methods can be employed. Site directed mutagenesis can be used to identify critical residues necessary for activity of a particular hemoglobin chain. Regions of a chain which is known to be active as a stem cell inhibitor (e.g., alpha chain) can be substituted with regions from a related but inactive protein (e.g., myoglobin) and tested in stem cell assays, allowing for identification of regions necessary for activity. Such

identified regions can be expressed as peptides and tested for activity in stem cell cycling assays.

Homologous or analogous versions of INPROL from other species are employed in various veterinary uses, similar to the therapeutic embodiments of the invention described above.

INPROL at stem cell inhibitory amounts act on cycling stem cells by reversibly placing them in an undividing or slowly dividing "resting" state. When it is desirable to stimulate the quiescent stem cells into division, e.g., after treatment of a patient with cancer chemotherapy agents or radiation, INPROL at stem cell stimulatory amounts can be used. Alternatively, or in addition, colony-stimulating factors and other hematopoietic stimulants are administered to the subject. Examples of such factors include but are not limited to: M-CSF (CSF-1), GM-CSF, G-CSF, Megakaryocyte-CSF, thrombopoieitin, stem cell factor or other cytokines, such as IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL9, IL-11, IL-12, IL-13, IL-14, or erythropoietin .

INPROL polypeptides or active fragments having stem cell inhibitory activity are purified or synthesized by conventional chemical processes combined with appropriate bioassays for stem cell inhibitory activity, as exemplified in the protocols described below.

In one embodiment of the invention, a therapeutically effective amount of the INPROL protein or a therapeutically effective fragment thereof is employed in admixture with a pharmaceutically acceptable carrier. This INPROL composition is generally administered by parenteral injection or infusion. Subcutaneous, intravenous, or intramuscular injection routes are selected according to therapeutic effect achieved.

When systemically administered, the therapeutic composition for use in this invention is in the form of a pyrogen-free, parenterally acceptable aqueous solution. Pharmaceutically acceptable sterile protein solution, having due regard to pH, isotonicity, stability, carrier proteins and the like, is within the skill of the art.

Also comprehended by the invention are pharmaceutical compositions comprising therapeutically effective amounts of peptide or polypeptide products of the invention together with suitable diluents, preservatives, solubilizers, emulsifiers, adjuvants and/or carriers useful in INPROL therapy. A "therapeutically effective amount" as used herein refers to that amount which provides a therapeutic effect for a given condition and administration regimen. Such compositions are liquids, gels, ointments, or lyophilized or otherwise dried formulations and include diluents of various buffer content (e.g., Tris-HCl, acetate, phosphate), pH and ionic strength, additives such as albumin or gelatin to prevent adsorption to surfaces, detergents (e.g., Tween 20, Tween 80, Pluronic F68, bile acid salts), solubilizing agents (e.g., glycerol, polyethylene glycol), anti-oxidants (e.g., ascorbic acid, sodium metabisulfite), preservatives (e.g., Thimerosal, benzyl alcohol, parabens), bulking substances or tonicity modifiers (e.g., lactose, mannitol), covalent attachment of polymers such as polyethylene glycol to the protein, complexation with metal ions, or incorporation of the material into or onto particulate preparations of polymeric compounds such as polylactic acid, polyglycolic acid, hydrogels, etc. or into liposomes, niosomes, microemulsions, micelles, unilamellar or multilamellar vesicles, biodegradable injectable microcapsules or microspheres, or protein matrices, erythrocyte ghosts, spheroplasts, skin patches, or other known methods of releasing or packaging pharmaceuticals. Such compositions will influence the physical state, solubility, stability, rate of *in vivo* release, and rate of *in vivo* clearance of INPROL. Controlled or sustained release compositions include formulation in lipophilic depots (e.g., fatty acids, waxes, oils). Also comprehended by the invention are particulate compositions coated with polymers (e.g., poloxamers or poloxamines) and INPROL coupled to antibodies directed against tissue-specific receptors, ligands or antigens or coupled to ligands of tissue-specific receptors. Other embodiments of the compositions of the invention incorporate particulate forms of protective coatings, protease inhibitory factors or permeation enhancers for various routes of administration, including parenteral, pulmonary, nasal,

topical (skin or mucosal) and oral. In another embodiment, the composition containing INPROL is administered topically or through a transdermal patch.

In one embodiment, the compositions of the subject invention are packaged in sterile vials or ampoules in dosage unit form.

The invention also comprises compositions including one or more additional factors such as chemotherapeutic agents (e.g., 5-fluorouracil (5FU), cytosine arabinoside, cyclophosphamide, cisplatin, carboplatin, doxyrubicin, etoposide, taxol, alkylating agents), antiviral agents (e.g., AZT, acyclovir), TNF, cytokines (e.g., interleukins), antiproliferative drugs, antimetabolites, and drugs which interfere with DNA metabolism.

The dosage regimen involved in a method for treating the subject anticipating exposure to such cytotoxic agents or for treatment of hyperproliferating stem cells is determined by the attending physician considering various factors which modify the action of drugs; e.g., the condition, body weight, sex, and diet of the patient, the severity of any infection, time of administration and other clinical factors.

Following the subject's exposure to the cytotoxic agent or radiation, the therapeutic method of the present invention optionally employs administering to the subject INPROL at stem cell stimulatory amounts optionally including one or more lymphokines, colony stimulating factors or other cytokines, hematopoietins, interleukins, or growth factors to generally stimulate the growth and division of the stem cells (and their descendants) inhibited by the prior treatment with INPROL. Such therapeutic agents which encourage hematopoiesis include IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, Meg-CSF, M-CSF (CSF-1), GM-CSF, G-CSF or erythropoietin. The dosages of these agents are selected according to knowledge obtained in their use in clinical trials for efficacy in promoting hematopoietic reconstitution after chemotherapy or hematopoietic stem cell transplant. These dosages would be adjusted to compensate for variations in the physical condition of the patient, and the amount and type of chemotherapeutic agent or radiation to which the

subject was exposed. Progress of the reversal of the inhibition of the stem cells caused by administration of INPROL in the treated patient is monitored by conventional methods.

In the treatment of leukemia, it is beneficial to administer both INPROL to inhibit normal stem cell cycling and a stimulator of leukemic cell growth, such as IL-3 or GM-CSF, simultaneously with the cytotoxic drug treatment or during irradiation. By this protocol, it is possible to achieve the greatest differences between the cycling statuses and drug sensitivities of normal and leukemic cells.

Example 1: *In Vivo* Stem Cell Proliferation Inhibition Assay

For the detection of stem cells proliferation the number of CFU-S in S-phase of the cell cycle was measured by the ^{3}H-Thymidine "suicide" method (Becker *et al.*, Blood 26:296-308, 1965).

Immature hematopoietic progenitors--Colony Forming Units in spleen (CFU-S)--can be detected *in vivo* by forming macroscopic colonies in the spleens of lethally irradiated mice, 8-12 days after the intravenous injection of hematopoietic cells (Till & McCulloch, 1961).

For the standard CFU-S proliferation assay the method of ^{3}H-Thymidine "suicide" is usually applied (Becker *et al.*, 1965). The method is based on incorporation of radiolabelled Thymidine, (^{3}H-Thymidine) a precursor of DNA into cells during DNA synthesis. The CFU-S which are in S-phase of the cycle at the time of testing, are killed by the high radioactivity and therefore not able to form colonies in spleen. Thus, the difference between the number of CFU-S formed by the injection of the cell sample incubated without ^{3}H-Thymidine and the same cells incubated with ^{3}H-Thymidine shows the percentage of the proliferating CFU-S in the original sample.

The inhibitor testing can not be done with the bone marrow stem cell population from unstimulated animals, as far as the inhibitor only effects cycling CFU-S, which are as low as 7-10% of the total CFU-S population in the bone marrow of normal mice.

To stimulate CFU-S proliferation, phenylhydrazine (PHZ), or sublethal irradiation were used (Lord, 1976).

We have developed the method of using testosterone-propionate (TSP) based on its stimulatory effect on CFU-S cycling (Byron *et al.*, Nature 228:1204, 1970) which simplified the testing and did not cause any side effects. The TSP induced stimulation of CFU-S proliferation within 20-24 hours after injection and the effect could be seen for at least 7 days.

The procedure used for the screening of the fractions during purification of the Inhibitor was as follows:

Mice: BDF_1 or CBF_1 mice strains were used throughout all testing.

Donor mice were treated with a 10 mg/100 g dose of TSP by intraperitoneal injection of 0.2 ml/mouse in order to induce 30-35% of the CFU-S into S-phase.

Twenty-four hours later the bone marrow is taken from the femurs for the cell suspension preparation. Five to ten million cells per ml are then incubated with different control and test fractions for 3.5 hours at 37°C in water bath, with two tubes for each group (one for hot (radioactive) and one for cold (non-radioactive)).

After 3.5 hours, ^{3}H-Thymidine (1 mCi/ml, specific activity 18-25 Ci/mmole) is added to each hot tube in a volume of 200 µl per 1 ml of cell suspension; nothing is added to the cold tubes. Incubation is continued for 30 more minutes at 37°C.

After the 30 minute incubation, the kill reaction is terminated by adding 10 ml of cold (4°C) medium containing 400 µg/ml nonradioactive Thymidine. Cells are washed extensively (3 times).

Cells are resuspended and diluted to a desirable concentration for the injections, usually 2-4 x 10^4 cells per mouse in 0.3-0.5 ml.

Recipient mice, 8-10 per group, are irradiated not later than 6 hours before the injections.

Recipient spleens are harvested on day 9-12 and fixed in Tellesnitsky's solution; the colonies are scored by eye score. The percentage of cells in S-phase are calculated using the formula.

$$\% S = \frac{a - b}{a} \times (100\%)$$

where a -- CFU-S number without ^{3}H-Thymidine

where b -- CFU-S number with ^{3}H-Thymidine

The test data of INPROL presented in Table 1 demonstrate that cycling stem cells after treatment with INPROL become resistant to the action of ^{3}H-Thymidine. For this and all of the following examples, the term "pINPROL" refers to the purified protein from porcine bone marrow. The same protection is seen for the S-phase specific cytotoxic drugs cytosine arabinoside and hydroxyurea (data not shown). If the treated stem cells are then washed with the cold media containing non-radioactive Thymidine, the surviving stem cells proliferate in mouse spleens to form colonies normally.

Table 1

Inhibitory Activity Of pINPROL On CFU-S Proliferation
During Four Hour Incubation With Bone Marrow Cells

Group	-^{3}H-TdR	+ ^{3}H-TdR	Percent CFU-S Killed by ^{3}H-TdR
No incubation	22.2 ± 2.0*	13.7 ± 2.4*	38.3 ± 1.7
4 Hour with Media	18.7 ± 3.0*	11.4 ± 1.3*	43.1 ± 1.4
4 Hour with pINPROL	21.2 ± 2.3*	20.7 ± 2.6*	2.1 ± 0.08

* CFU-S per 2 x 10^{4} cells

Example 2: *In Vitro* Stem Cell Proliferation Inhibition Assay

Using the following test system (Lord *et al.*, in The Inhibitors of Hematopoiesis pp. 227-239, 1987) the direct effect of INPROL was shown. The multilineage factor (IL-3) dependent stem cell line, FDCP mix A4 (A4), was maintained in IMDM medium supplemented with 20% horse serum and 10% WEHI-3-conditioned medium as a source of colony-stimulating IL-3.

A tritiated Thymidine incorporation assay was used to measure proliferation: A4 cells (5×10^4 in 100 µl medium with 20% horse serum and 50% of WEHI-3 CM) were incubated at 37°C in 5% CO_2 for 16 hours.

pINPROL or the crude BME (fraction IV) were added at the start. Tritiated thymidine (^{3}H-Tdr) 3.7KBq in 50 µl at 740 GBq/mmole) was then added to each group for a further 3 hours of incubation. The level of proliferation was measured by harvesting cells and the % inhibiton calculated using the formula

$$\% \text{ Inhibition} = \frac{\text{cpm without INPROL - cpm with INPROL}}{\text{cpm without INPROL}} \times (100\%)$$

Incorporation of tritiated thymidine (^{3}H-Tdr) by FDCPmix-A4 cells grown in the presence of graded doses of normal bone marrow extract or pINPROL is depicted on Figure 6. It can be seen that purified composition of pINPROL is at least 1,000 times more active than the starting material. Time of exposure (16 hours) is an important factor for effective inhibition and shows the evidence of the direct effect of pINPROL on stem cells of the A4 cell line.

Example 3: Inhibition of CFU-S Proliferation by INPROL Injected *in vivo* Doses and the Duration of the Effect

The studies of the effect of INPROL injected *in vivo* revealed that INPROL can effectively block the recruitment of CFU-S into cycle, thus protecting those cells from the cytotoxic effect of further treatment, showing its potential for clinical use.

The experimental protocol had two goals: to check the effect of INPROL on CFU-S when injected *in vivo* and to define the effective duration of INPROL activity in relation to cycling stem cells.

To stimulate CFU-S proliferation, the injection of testosterone-propionate was used based on the effect mentioned above in Example 1.

Mice BDF1 were injected with TSP (10 mg/100 g) on Day 0; 24 hours later mice of each experimental group (4 mice per group) received a single pINPROL injection at doses of 0 μg, 5 μg, 10 μg, and 15 μg/mouse i.p.

Twenty-four hours after pINPROL injection, mice were sacrificed and the percent of cycling CFU-S was measured by the assay described in Example 1. TSP injection induced about 50% CFU-S into cycling in comparison with 7% in untreated mice. pINPROL in doses as low as 2 μg/mouse was able to inhibit TSP induced proliferation down to the normal level.

For the duration of the effect evaluation, one group of mice (21 mice per group) was injected with TSP only and another group was injected both with TSP and pINPROL (24 hours after TSP). The CFU-S cycling was measured every 24 hours during a week by taking 3 donors from each group and measuring CFU-S cycle status in their bone marrow by method described (see Example 1). Data presented in Figure 7 show that while the duration of the effect of TSP is at least 7 days, a single injection of INPROL can place CFU-S into quiescence and keep them out of cycle for no more than 48-72 hours. Since the majority of chemotherapeutic agents used for cancer and leukemia chemotherapy

have a relatively short *in vivo* half-life, usually less than 24 hours, the INPROL effect according to the data obtained is maintained for longer than the effective time during which the chemotherapeutic agents like cytosine arabinoside or hydroxyurea are active *in vivo*. More importantly, for chemotherapeutic and radiation treatments having longer intervals (more than 24 hours and less than 96 hours) between the first (non-damaging for the stem cells) and the second (damaging to the CFU-S) treatments, a single injection of INPROL during the intervals between the two applications of chemotherapeutic agent or radiation should be sufficient. For several repeatable cycles of cytotoxic therapy or radiation the same strategy could be applied based on the duration of the INPROL effect.

Example 4: Most Primitive Hematopoietic Stem Cells Stimulated to Cycle Rapidly After Treatment with 5-FU are Protected by INPROL from the Second 5-FU Exposure

The drug 5-fluorouracil (5-FU) drastically reduces the number of cells in the myeloid and lymphoid compartments. It is usually thought of as being cell-cycle specific, targeting rapidly proliferating cells, because incorporation of the nucleotide analogue into DNA during S-phase of the cell cycle or before results in cell death. The long-term survival and immunohematopoietic reconstitution of the bone marrow of mice is not affected by a single dose of 5-FU; however, it was demonstrated (Harrison *et al.* Blood 78:1237-1240, 1991) that pluripotent hematopoietic stem cells (PHSC) become vulnerable to a second dose of 5-FU for a brief period about 3-5 days after the initial dose. It can be explained that PHSC normally cycle too slowly for a single dose of 5-FU to be effective and are stimulated into rapid cycling by stimuli resulting from the initial 5-FU treatment. We have proposed that PHSC can be returned to a slow cycle status by INPROL and thus protected from the second 5-FU treatment.

The mice used in these experiments were BDF1 male mice. A stock solution of 5-FU (Sigma) was prepared in physiologic saline at a concentration of 10 μg/ml. Each

treated mouse received 2 mg of 5-FU per 10 g body weight via a tail vein at Day 0 of the experiment; 24 hours later mice were injected with pINPROL (10 μg/100 g of body weight) intraperitoneally and on Day 3 were injected with the second dose of 5-FU. The survival study was conducted by monitoring the death of mice in experimental (treatment with pINPROL) and control groups of 30 mice each. The survival curves are shown in Figure 8.

Example 5: Effects of Pre-Incubation with INPROL vs. MIP-1α in Bone Marrow Cells

The purpose of this experiment was to compare the inhibitory effects of pre-incubation with pINPROL and MIP-1α on mouse bone marrow cells *in vitro*.

The following procedure was used:

in vivo: BDF1 mice, 6-15 weeks of age, are injected with 200 mg/kg 5FU i.p. 48 hours before harvesting marrow from the femurs.

in vitro: A single cell pooled suspension is counted and 5 x 10^6 cells are incubated in a total of 2 mls with or without pINPROL or MIP-1α, with 5% horse serum, IMDM media with added L-glutamine, at 37°C and 5% CO_2 for 4 hours. The cells are then washed twice and recounted. They are plated in methylcellulose in the following final conditions:

0.8% methylcellulose

25% horse serum

20 ng/ml recombinant murine IL3

L-glutamine added

5x 10^5 cells per ml

IMDM media

Plates were incubated for 11 days at 37°C and 5% CO_2 in 100% humidity. Colonies more than 50 cells were counted.

Table 2

Groups	Colony Number	Percent of Control
Control	31.0	100%
pINPROL	21.25	68.5%
MIP-1α	35.25	114%

Example 6: INPROL inhibits HPP-CFC proliferation

An *in vitro* assay for assessing murine reconstituting stem cells and early precursors is the high proliferative potential colony (HPP-PFC) assay; other related assays, e.g., CFU-A, CFU-GM, CFU-E, and CFU-GEMM, detect progressively restricted progenitor populations (M. Moore, Blood 177:2122-2128, 1991). This example shows that pretreatment of cells with pINPROL inhibits their proliferation, whereas MIP-1α fails to do so under these experimental conditions.

BDF1 mice were treated with 5-fluorouracil (200 mg/kg i.p.) before their bone marrow was assayed for HPP-CFC numbers. Cells were washed by centrifugation and incubated at densities of 10^6 to $5x10^6$ /ml in medium with either no added agent (Controls), pINPROL (25 ng/ml) or MIP-1α (200 ng/ml) for 4 hours. After incubation, cells were washed and plated in agar (0.3%) with 30% FCS and combined conditioned medium from 5637 and WEHI-3B cell lines (7.5% of each conditioned medium, as recommended by Sharp *et al.*, 1991). Plating concentration was $5x10^4$ cells/ml in 60 mm dishes. Colonies were scored on day 14 and the results are indicated below.

Table 3

Group	HPP-CFU	% of Control
Control	15.5±1.2	100 %
pINPROL	8.3±0.7	53.5 %
MIP-1α	15.8±0.9	101%

According to these results, MIP-1α did not inhibit proliferation of the most immature precursors when present only during the pre-incubation period. pINPROL did effectively inhibit proliferation under these conditions, indicating fundamental differences between pINPROL and MIP-1α in terms of biological activity.

Example 7: INPROL Therapy Effect on the Recovery from Radiation-induced Bone Marrow Aplasia

Bone marrow aplasia is the primary limiting toxicity of radiation cancer therapy. It has been demonstrated that some growth factors (e.g., G-CSF, GM-CSF, erythropoietin) can accelerate recovery from radiation-induced bone marrow aplasia. The concept of protection by using an inhibitor of stem cell proliferation is a different and complementary approach in coping with hematological damage. To follow the treatment procedure developed earlier (Examples 3, 4) a model of lethal irradiation of mice was established. It is known in the art that mice receiving 9Gy of cobalt 60 start dying after 10-14 days; by Day 30, mortality approximates 50%. This lethal dose was used in our model by splitting it into two subsequent applications of 4.5Gy each with an interval 3 days between doses. Preliminary data showed that the survival curve in that model was very close to that known for a single irradiation with 9Gy; moreover the test for the CFU-S proliferation showed that 24 hours after the first irradiation, 35-50% of CFU-S are induced to

proliferate. Such cells can be protected by a stem cell inhibitor delivered prior to the second dose.

To examine this possibility, mice (50 mice/group) received 4.5Gy on Day 0. Twenty four hours later, one group received pINPROL (2 μg/mouse i.p.) and another, control group was injected with saline. The second dose of radiation (4.5 Gy) was given on Day 3.

Fig. 9 shows the increased survival after a single dose of pINPROL. The conditions of the model are clinically relevant for treating any cancer, including those characterized by solid tumors; such treatment would be administered to a patient having cancer by delivering an effective dose of INPROL between two consecutive dosages of radiation, thereby allowing greater dosages of radiation to be employed for treatment of the cancer. It should also be possible to extend this modality to chemotherapeutic agents.

Example 8: INPROL Use for the Autologous Bone Marrow Transplantation

Bone marrow transplantation is the only known curative therapy for several leukemias (CML, AML, and others). *Ex vivo* conditioning of autologous BMT for infusion should provide potential autologous sources of normal stem cells free of leukemic contamination and able to repopulate the recipient's hematopoietic system to allow aggressive and effective therapy.

1. Long-term Bone Marrow Culture L1210 Leukemia Model For The Study Of INPROL Effect Preserving Normal Hematopoiesis During Purging With AraC.

Long-Term Bone Marrow Cultures (LTBMC) were established according to Toksoz *et al.* (Blood 55:931-936, 1980) and the leukemic cell line L1210 was adopted to the LTBMC by co-cultivation during 2 weeks. The simultaneous growth of normal and

leukemic progenitors occurred in these combined LTBMC/L1210 cultures, similar to the situation in the bone marrow of a leukemic patient. Discrimination between normal colony forming units CFU and leukemic CFU was possible by growing them as agar colonies in the presence or absence of the conditioned medium from WEHI-3 (a murine IL-3 producing cell line). Normal cells undergo apoptosis in the absence of IL-3 whereas leukemic cells can form colonies in its absence. Suspension cells from LTBMC-L1210 composition give approximately 150 colonies in presence of IL-3 (normal hematopoietic clones) and 70 colonies when growing without IL-3 (leukemic clones) per 50,000 cells plated.

The procedure of purging was as follows: on Day 0 all suspension cells and media (10 ml/flask) were taken off the flasks with LTBMC-L1210 and replace with 2 ml of media containing 200 μg cytosine arabinoside (AraC) (Tsyrlova *et al.* in Leukemia: Advances in Biology and Therapy v. 35, 1988); after 20 hours of incubation, flasks were washed out and replaced with 2 ml of fresh media alone (control group) or media containing pINPROL at 25 ng/ml for 4 hours. After this preincubation, cells were incubated again with 100 μg/flask AraC for 3 hours at 37°C. Each group contained 4 flasks. LTBMC-L1210 cultures were washed 3 times and replaced with fresh LTBC media; they were maintained as before for the regeneration studies for 3-4 weeks.

Data are presented in Fig. 10. There was no cell growth seen in control cultures treated with AraC only, while in INPROL protected flasks regeneration of hematopoiesis occurred much more rapidly due to proliferation of progenitors from the adherent layer. Moreover, the cells from the experimental group when plated in agar grew only in the presence of IL-3 giving about 100 CFU per 50,000 cells; no leukemic cell growth was observed at least during 4 weeks. Thus, marrow treated *ex vivo* with an effective dose of AraC in combination with INPROL can be purged of cancerous cells while the stem cells are be protected. It should be possible to extend this modality to other forms of chemotherapy or radiation treatments.

2. Marrow Repopulating Ability (MRA) And Thirty Days Radioprotection Are Increased By INPROL Treatment *In Vitro.*

MRA, the ability of cells to repopulate the bone marrow of lethally irradiated mice, together with the ability to confer radioprotection for 30 days, is a direct *in vivo* measurement of the potential to rescue myelosuppressed animals (Visser *et al.* Blood Cells 14:369-384, 1988).

For radioprotection studies BDF1 mice were irradiated with 9.5Gy and restored by transplantation of bone marrow from testosterone-stimulated donors. One group of recipients was restored by bone marrow cells preincubated for 4 hours with medium (controls - group A) and another (group B) with 25 ng/ml pINPROL. Cells in both groups were washed and 30,000 cells per mouse were transplanted into irradiated animals. The survival data are shown (Fig. 11). The sum of 3 experiments is depicted, with controls normalized to 100%. pINPROL incubation increased the survival of mice from 36.5% in control group up to 61.8% by Day 30.

The increase of MRA induced by preincubation with INPROL could be one of the mechanisms in the improving of the radioprotection. To examine this hypothesis, MRA was measured according to Visser *et al.* (*op. cit.*). Briefly, the donor BDF1 mice were pretreated with testosterone, their bone marrow was preincubated with medium or pINPROL for 4 hours and injected into irradiated animals. On Day 13, the bone marrow cells from recipient femurs were plated in agar in 3 different concentration (0.01, 0.05, 0.1 equivalent of a femur) in the presence of 20% of horse serum and 10% of WEHI-CM. The number of Day 7 colonies represented the MRA as far as the colony-forming cells in the bone marrow of recipients at the time were the progenitors of the donor's immature stem cells.

As can be seen on Fig. 12 the MRA of the preincubated with INPROL cell population is greater than in the control group (B).

Example 9: Antihyperproliferative Effect Of INPROL On Stem Cells Can Change Their Differentiation Abnormalities.

Hyperproliferation of CFU-S is not only seen during restoration from cytotoxic drugs or irradiation but also as a consequence of normal aging, and is thought to be a major feature in Myelodysplastic Syndrome (MDS). It is accompanied by the differentiation disturbances such as a prevalence of the erythroid differentiation while the differentiation along the granulocytic pathway is reduced.

Bone marrow cells were incubated for 4 hours at 37°C with 25 ng/ml of pINPROL or media (Control), washed and then plated in agar with 20% of horse serum, 2U/ml Erythropoietin, and 10% WEHI-CM. The number of BFU-E and GM-CFU colonies were scored on Day 7. Data presented in Table 4 are summarized from 3 experiments - 4 animals per point were taken for each group; 4 dishes were plated.

As is obvious from Table 4, the incubation of normal bone marrow (NBM) from intact young animals (BDF1 8-12 weeks old) with INPROL did not change the number or proportion of different types of colonies. BDF_1 donors pretreated with Testosterone Propionate (TSP) showed the same increase in CFU-S proliferation as was seen before (Example 1, 3, 4) a slight increase in the erythroid progenitor number (BFU-E colonies) and a decrease in GM-CFU, which were completely abrogated by the incubation with INPROL. In addition, the abnormally high level of CFU-S proliferation was returned to 10% of CFU-S in S-phase of cell cycle. CFU-S hyperproliferation is known to be a feature of some mouse strains susceptible to viral leukemia induction, for example Balb/c mice (Table 4), and can also be observed in older animals (Table 4). The same redistribution of committed progenitors seen in TSP treated BDF1 mice is observed in

Balb/c and in older (23-25 month old) BDF1, which have in common the abnormally high level of CFU-S proliferation. The correction of both the proliferation of CFU-S and the differentiation was induced by the incubation with INPROL. What is even more clinically relevant, the study showed that the *in vivo* injection of INPROL (2 μg/mouse) affected both proliferation of CFU-S and the ratio of erythroid (BFU-E) and GM-colonies (Table 4).

Table 4

INPROL Effect On CFU-S Differentiation Into Committed Progenitors BFU-E and CFU-GM

Donors Of Bone Marrow	pINPROL	Percent CFU-S Killed by ^{3}HTdR	BFU-E	CFU-GM
BDF_1 Young	-	12.0 ± 0.3	28.33 ± 1.91	46.22 ± 3.44
	+	15.0 ± 1.3	22.00 ± 3.74	47.70 ± 3.72
BDF_1 Old	-	47.1 ± 1.9	43.75 ± 1.54	24.0 ± 1.33
	+	11.4 ± 0.7	15.25 ± 1.45	44.0 ± 7.63
BDF_1 Stimulated by TSP	-	53.2 ± 1.6	32.67 ± 2.44	15.71 ± 2.28
	+	7.2 ± 0.4	12.00 ± 1.83	35.50 ± 1.4
Balb/C	-	57.0 ± 1.9	47.60 ± 2.96	33.57 ± 3.45
	+	23.0 ± 2.4	24.86 ± 2.53	70.60 ± 4.96

Example 10: Immunostimulatory Activity of INPROL

It has been observed that the incubation of bone marrow cells containing a high proportion of proliferating CFU-S with INPROL not only changes the cycling of CFU-S, but also their differentiation, switching the predominantly erythroid differentiation in favor of granulocytic and lymphoid progenitors. This property of INPROL is of importance due to the immunosuppression side effects of cytotoxic chemotherapy or radiotherapy, as well as the immunosuppression accompanying hyperproliferative stem cell disorders and aging.

The example shows the direct effect of INPROL on the differentiation of immature precursors from the Lymphoid Long Term Culture (LLTC) established according to Wittlock & Witte (Ann. Rev. Immun. 3:213-35, 1985) into pre-B progenitors, measured by the formation of colonies in methylcellulose containing IL-7.

LLTC were established as described and fed with fresh LLTC-media (Terry Fox Labs., Vancouver, Canada) twice a week. Nonadherent cells were harvested once a week, washed free of factors and incubated for 4 hours with 25 ng/ml pINPROL or medium alone for control. After the incubation, the cells were washed and plated at a concentration of 10^5 cells/ml in methylcellulose, containing 30% FCS, and 10 ng/ml of IL-7. Data from 3 weeks are shown in Figure 13. The number of large pre-B colonies varied in control, increasing with time, but preincubation with INPROL always stimulated the growth of colonies 4 to 8 fold above the control level. This demonstrates an immunostimulatory property of INPROL which is of use in correcting immunodeficient states and in increasing desired immune responses, e.g., to vaccination.

Example 11: INPROL Improves Repopulating Ability of Stem Cells -- Long Term Culture Initiating Cells from Patient with CML

Chronic myeloid leukemia (CML) is a lethal malignant disorder of the hematopoietic stem cell. Treatment of CML in the chronic phase with single-agent chemotherapy, combination chemotherapy, splenectomy, or splenic irradiation can control clinical signs and symptoms, but does not significantly prolong survival. As CML progresses from the chronic to the accelerated stage, standard therapy is not effective. At present, bone marrow transplantation (BMT) is the only known curative therapy for CML. Therapy with unrelated donor BMT is difficult due to histoincompatibility problems. Fewer than 40% of otherwise eligible CML patients will have a suitably matched related donor; therefore autologous transplantation is preferred. *Ex vivo* conditioning of autologous BMT for infusion together with the ability to select non-leukemic (Ph-negative) myeloid progenitors from Ph-positive patients growing in Long Term Culture (LTC) suggest the potential of autologous sources of normal stem cells to allow aggressive and effective therapy of CML.

In the context of BMT, a hematopoietic stem cell can be defined as one having the ability to generate mature blood cells for extensive periods. We have used the human LTC system developed by C. Eaves & A. Eaves both for quantitating stem cell numbers and as a means to manipulate them for therapeutic use. This involves seeding cells onto a pre-established, irradiated human marrow adherent layer; these cultures are then maintained for 5 weeks. The end point is the total clonogenic cell content (adherent + non-adherent) of the cultures harvested at the end of this time. Clonogenic cell output under these conditions is linearly related to the number of progenitors (Long Term Culture Initiating Cells (LTC-IC)) initially added; the average output from individual human LTC-IC is 4 clonogenic progenitors per LTC-IC. It has been shown previously that when marrow from patients with CML is placed under similar conditions, leukemic (Ph-positive)

clonogenic cells rapidly decline. By using quantitation of residual normal LTC-IC, in patients with CML it is possible to select those likely to benefit from intensive therapy supported by transplantation of cultured autografts (Phillips *et al.*, Bone Marrow Transplantation 8:477-487, 1991).

The following procedure was used to examine the effect of INPROL on the number of clonogenic cells (LTC-IC) among bone marrow transplant cells established from the peripheral blood of a patient with CML.

Cultures were initiated as long term cultures on pre-irradiated stroma. The peripheral blood of a healthy donor was used as the control. Peripheral blood cells from a CML patient were preincubated with or without pINPROL (25 ng/ml) for 4 hours, washed and placed in the LTC-IC system for 5 weeks to determine the control number of LTC-IC. For experiments, other, parallel cultures were established for 10 days. The mixture of adherent and non-adherent cells from cultures growing for 10 days was preincubated with or without pINPROL and placed on pre-established feeders for an additional 8 weeks. The number of LTC-IC from each experimental culture was estimated by plating both the adherent and non-adherent cells in methylcellulose with the appropriate growth factors (Terry Fox Laboratories, Vancouver, Canada) and counting the resulting total number of colony forming cells. The LTC-IC values obtained using this procedure were derived from assessment of the total clonogenic cells (CFC) content using the formula:

$$\#\text{ LTC-IC} = \#\text{CFC} / 4$$

Data presented on Figure 14 show that there was no loss in LTC-IC during the first 10 days of culture initiated from the healthy donor's bone marrow and approximately 30% of the number of input LTC-IC were still present after 5 weeks in culture. The number of the CML patient's LTC-IC was drastically reduced to about 8% during the 10 day period and did not recover during further incubation, while the preincubation of cells with INPROL increased the LTC-IC level to 30% of initial number and it was maintained during 8 weeks.

Clinically relevant applications of INPROL predicted by these preliminary data include their use in strategies for selectively improving the normal stem cell content of fresh or cultured marrow transplants, strategies for enhancing the recruitment of residual normal stem cells *in vivo* also protocols for transferring new genetic material into human marrow stem cells for the further transplantation into patients.

Example 12A: A Method of Isolation of Immunoactive Inhibitor of Proliferation of Stem Cells From Bone Marrow Preparations

The bone marrow was isolated from pigs' ribs. The ribs from the pigs' carcasses were separated and cleaned from the muscle fibers and fat, cut into pieces and the bone marrow was extracted by a hydropress manufactured by the Biophyzpribor. The bone marrow cells are separated by centrifugation in a centrifuge K-70 at 2,000 rpm for 20 minutes. The extract supernatant is then successively subjected to ultrafiltration through Amicon USA membranes XM-100, PM30, PM-50. According to the analysis by electrophoresis, the main component of the product is albumin (see Fig. 1).

Biochemical Purification

The bone marrow extract and protein components of the fractions were analyzed at every step of purification by gel electrophoresis in 10% polyacrylamide, containing 0.1% sodium dodecyl sulfate. Up to 7% of sodium dodecyl sulfate and up to 0.5-1% of mercaptoethanol were added to the samples which were incubated for 5 minutes at 70°C prior to loading on the gel.

The electrophoresis was conducted at 20Y cm of the gel for five hours. Then the gel was stained in 0.25% Coomassie CBBC250 in a mixture of ethanol:water:acetic acid 5:5:1 for one hour at 20°C and washed in several changes of 7% acetic acid. The

activity of the product was evaluated by the method of inhibition of proliferation of stem hematopoietic cells (CFU-S). The method is detailed hereafter.

Stage 1. Purification by precipitation with ammonium sulfate.

The activity was purified by precipitation with ammonium sulfate at 25% with saturation of 40 to 80% which was selected based on the results in Table 5.

Table 5

Saturation(%)	0-40	40-60	60-80	80-100
Activity (%)	37.2-35.4 =1.8%	37.2-1.8 =35.4%	37.2-12.8 =24.4%	37.2-26.1 =11.1%

The amount of the preparation used for testing after each step of purification was determined in accordance with the level of purification and equivalent to the dose of 2 x 10^{-2} mg of the initial product. Activity was determined by the formula:

% Change = %Sa -%Sb

where %Sa is %S in control

%Sb is %S after incubation with the test fraction.

The fraction was desalted in order to lower the concentration of ammonium sulfate 20 times before each testing of activity and before each following purification step.

Stage 2. The impure inhibitor from Stage 1 is applied after desalting and fractionated utilizing ion exchange chromatography, here DEAE 23 cellulose, and then eluted with a gradient of sodium acetate buffer (pH 6.0).

The active fractions of inhibitor elute between 3-5 mM.

The volume of the column was 1 ml and speed of elution was 4 ml/hour. The detection was conducted by the chromatograph Millicrome at 230 and 280 nm. Fraction 1 (see Fig. 2) which exhibited the highest activity was isolated and eluted in 5 mM sodium acetate buffer (see Table 6).

Table 6

Fractions	1	2	3	4	5
Activity	46.3-0 =46.3%	46.3-14.1 =32.2%	46.3-42.1 =4.2%	46.3-19.6 =26.7%	46.3-45.1 =1.2%

The electrophoresis data indicates that the main protein contaminant - albumin (see Fig. 3) is removed from this fraction which leads to an additional fourfold purification.

Stage 3. The partially purified inhibitor from Stage 2 is applied directly to a G-75 Sephadex column.

The volume of the column is 20 ml (20 X 1), the elution rate is 2 ml/hour. The elution buffer is 50 mM NaCl, l0 mM Tris-HCl, pH 7.5. Detection was conducted on a chromatograph Millichrome at 230 and 280 nm. Fraction 5 which had the highest activity was isolated.

Table 7

Fractions	1	2	3	4	5
Activity	42.2-19.1 =23.1%	42.2-35.2 =7.0%	42.2-21.5 =20.7%	42.2-38.8 =3.4%	42.2-0 =42.2%

Stage 4. Reverse-phase chromatography (Pharmacia FPLC System) utilizing Pro-REC columns is performed on an Ultrasfera matrix. Protein is eluted using 0.1% trifluoracetic acid in an acetonitrile gradient.

The homogeneity of a product with MW 16-17kD is equal to 90% as was shown in analyzing the acrylamide/sodium dodecyl sulfate gel (see Fig. 6). The result is represented in Fig. 4. Activity is determined on fraction 5. The final yield of the product is 5%. As a result, the total amount of protein with MW 16 kD after the purification is 650 ng/ml of the initial product. During the purification process the product was submitted to heat incubation at 70°C for several minutes but no loss of biological activity was detected.

Example 12B: Alternative method for isolating larger quantities of INPROL

Initial isolation

Ribs from fresh pig carcasses are cleaned of muscle fibers and fat, then cut to pieces and soaked in phosphate-buffered saline in the ratio 1:1 (weight/volume). The obtained mixture is crushed by hydraulic press to separate bone marrow from solid bone material.

The suspension of bone marrow cells is collected and filtered free of solid particles through four layers of the cheese-cloth. The filtrate is incubated at 56°C for 40 minutes, then cooled in an ice-bath to 4°C. The resulting precipitate is removed by centrifugation at 10,000 g for 30 minutes at 4°C and discarded.

The clarified supernatant is added dropwise during 30 minutes to 10 volumes of stirred ice-cold acetone containing 1% by volume of concentrated hydrochloric acid. The resulting mixture is kept at 4^0C for 16 hours for complete formation of the precipitate. Then the precipitate is pelleted by centrifugation at 20,000 g for 30 minutes at 4°C. This pellet is washed with cold acetone and dried.

HPLC Purification

The pellet is dissolved in HPLC eluent buffer A containing 5% acetonitrile (MeCN) and 0.1% triflouroacetic acid (TFA) to final protein concentration 8-10 mg/ml. This solution (0.5-0.6 ml) is loaded onto 250 x 4.6 mm HPLC column packed with Polisil ODS-300 (10 mcm) and equilibrated with the same buffer A.

The elution is accomplished by gradient of buffer B (90% MeCN, 0.1% TFA) in buffer A at the flow rate of 1 ml/min according to the following program:

Time, min	% of B
0	0
4	0
5	25
25	90

An additional step of 100% B for 5 minutes is used to wash the column prior to re-equilibration. Then the column is equilibrated again for returning it to the initial state, and the next portion of the protein solution can be loaded. A typical chromatogram is shown in Fig. 5.

During the separation the column effluent is monitored at 280 nm for the detection of protein peaks. Fractions containing the protein material are collected, separated peaks are pooled and rotary evaporated at 30°C to dryness. The obtained residues are dissolved in distilled water and assayed by bioactivity test and by SDS-PAGE (14% gel, reducing conditions). The peak containing the active material is eluted between 70 and 80% of the buffer B and contains the main protein band of 16 kD and the traces of faster moving proteins as assayed by SDS-PAGE.

An analysis of the material obtained by collecting only the second major HPLC peak is shown in Figure 15 (A and C). Material containing both peaks (e.g., Fig. 5) will be referred to herein as pINPROL Preparation 1 and those consisting of only the second peak will be referred to as pINPROL Preparation 2. 500 ug of this active, purified pINPROL Preparation 2 was loaded onto a C4 reverse phase column (Vydac) and eluted using a linear gradient of 595% acetonitrile in 0.1% trifluoroacetic acid. The material eluted as a single peak at 53% acetonitrile (Fig. 15A). When 250 μg of MIP-1α (R&D Systems), however, was run under identical conditions, it eluted at 43.9% acetonitrile (Fig. 15B - note that earlier peaks prior to 14% acetonitrile are artifactual and due to air bubbles in the detector). Thus, naturally occuring INPROL is substantially more hydrophobic than MIP-1α under these conditions. TGFβ is known to elute at lower

concentrations than that observed for pINPROL under these conditions (Miyazono *et al.* J. Biol. Chem. 263:6407-15, 1988).

A gel of the eluted pINPROL material is shown in Figure 15C. Lane 1 is the crude material, Lane 2 is molecular weight markers and Lane 3 is the purified material. There are two major bands, one at approximately 14 kD and one at approximately 35 kD. It is believed that the 35 kD band is a multimeric form of the 14 kD band.

Example13A: Active INPROL Preparations Contain Hemoglobin Beta Chain

pINPROL was prepared as shown in Fig. 5 (i.e., pINPROL Preparation 1 (see Example 12B)). The material was run on SDS-PAGE and transferred to nitrocelluose using standard techniques. The material was subjected to N-terminal sequence analysis using an ABI 477A protein sequencer with 120A Online PTH-AA analyzer using standard techniques. The following N-terminal sequence was obtained:

VHLSAEEKEAVLGLWGKVNVDEV....

Computer search of the protein databases reveal that this sequence has identity with the N-terminal sequence of the beta chain of porcine hemoglobin (cf. Fig. 16C).

Example13B: Active INPROL Preparations Contain Hemoglobin Alpha Chain

As shown in Fig. 15C, protein purified by collecting the second major peak shown in Fig. 5 (i.e., pINPROL Preparation 2) resulted in two major bands corresponding to molecular weights of approximately 15K and 30K, as well as several minor bands. SDS-PAGE gels were transferred to nitrocellulose using standard techniques and

individual bands were excised and subjected to N-terminal sequence analysis as in Example 13A. The following N-terminal sequence was obtained for the 15kD band:

VLSAADKANVKAAWGKVGGQ.....

The 30 kD band was subjected to limited proteolytic digest and the following internal sequence was obtained: * * FPHFNLSHGSDQVK....

The first sequence shows identity with the N-terminal sequence of porcine hemoglobin alpha chain whereas the second sequence shows identity with residues 43-56 of the porcine hemoglobin alpha chain (see Fig. 16C for a sequence comparison of human, murine and porcine alpha and beta hemoglobin chains). Repeat sequencing of these bands as well as of some of the minor bands consistently yielded portions of the alpha globin sequence. Thus the various bands observed in Fig. 15C represent either fragments or aggregates of the porcine hemoglobin alpha chain.

Example 13C: Further characterizations of Porcine INPROL

In order to further compare pINPROL to porcine hemoglobin, twice crystallized porcine hemoglobin was obtained from Sigma Chemical Company and subjected to reverse phase HPLC as described in Example 12B for Figure 15. As can be seen in Figure 17, the HPLC chromatogram of intact hemoglobin is similar to that seen for the pINPROL Preparation 1. Further, in a direct comparison, the pINPROL Preparation 2 shown in Fig. 17A (i.e., derived from the second peak of Fig. 5) is seen to overlap with that of the second two peaks of porcine hemoglobin (Fig. 17B), with retention times of 52.51 and 52.25 minutes for the major peaks, respectively. It should be noted that heme co-migrates with the first major peak in hemoglobin, in this case at 49.153 minutes; heme

is therefore a component of pINPROL Preparation 1 but not of Preparation 2. This is confirmed by the lack of absorption of this pINPROL preparation at 575 nm, a wavelength diagnostic for the presence of heme.

The predicted molecular weights of porcine hemoglobin alpha and beta chains are 15038 Daltons and 16034 Daltons, respectively. As can be seen in the SDS-PAGE chromatogram in Figure 18, the first two peaks are composed of the higher molecular weight chain and the second two are composed of the lower molecular weight chain. Thus the first two peaks appeared to represent hemoglobin beta chain and the second two peaks to represent hemoglobin alpha chain.

Additional separations of porcine hemoglobin were carried out using a shallow elution gradient (Fig. 21). N-terminal analyses of these peaks demonstrated that the first peak is porcine alpha chain and the second porcine beta chain. Bioassay results confirm that both isolated hemoglobin chains are biologically active (e.g., Examples 14 and 15).

In order to further compare pINPROL Preparation 2 and hemoglobin beta chain, 2-dimensional electrophoreses were conducted (Fig. 19). As a first dimension, isoelectric focusing was carried out in glass tubes using 2% pH 4-8 ampholines for 9600 volt-hours. Tropomyosin (MW 33 kD, pI 5.2) was used as an internal standard; it's position is marked on the final 2D gel with an arrow. The tube gel was equilibrated in buffer and sealed to the top of a stacking gel on top of a 12.5% acrylamide slab gel. SDS slab gel electrophoresis was carried out for 4 hours at 12.5 mA/gel. The gels were silver stained and dried.

A comparison of the 2D electrophoretic patterns revealed only one or two minor spots that are different between HPLC purified hemoglobin beta chain and the pINPROL Preparation 2. Western analyses, using anti-porcine hemoglobin antibodies and either 1D or 2D electrophoresis, confirm the presence of beta hemoglobin in the preparation. Thus the active pINPROL Preparation 2, prepared according to Example 12B, is substantially porcine hemoglobin beta chain.

Example 14: Hemoglobin Alpha Chain, Hemoglobin Beta Chain or Intact Hemoglobin Exhibit Stem Cell Inhibitory Activity

To confirm that hemoglobin beta chain has INPROL activity, a suicide assay using bone marrow from testosterone-treated mice was conducted using the methodology described in Example 1 using material purified as in Example 12B. As shown in Table 8, 15% of normal mouse bone marrow cells were killed as opposed to 36% in the testosterone-treated animals. As expected, this indicated that testosterone treatment increases the percentage of cells in cycle (thus rendering them more susceptible to killing - e.g., Example 1). In sharp contrast, cells from testosterone-treated animals incubated with either pINPROL or purified hemoglobin beta chain at 40 ng/ml showed a dramatic lowering of the percentage of cells in cycle from 36% to 0% and to 7%, respectively. The higher dose of 200 ng was less effective for both proteins. As a positive control, the previously characterized stem cell inhibitor MIP-1α reduced cycling to 13%.

A similar assay can be performed *in vitro*, using the cycling status of CFU-MIX instead of CFU-S. The assay is performed as described above for the CFU-S assay except that cytosine arabinoside (Ara C, 30 micrograms/ml) is used as the cycle-specific toxic agent instead of high dose tritiated thymidine (see B.I. Lord in Haemopoiesis - A Practical Approach, N.G. Testa and G. Molineux (Eds.), IRL Press 1993; Pragnell *et al.* in Culture of Hematopoietic Cells, R.I. Freshney, I.B. Pragnell and M.G. Freshney (Eds.), Wiley Liss 1994) and a mouse strain with high endogenous cycling rates (Balb/c) is used instead of testosterone-treated BDF_1 mice. As shown in Table 9, highly purified porcine beta chain, or highly purified porcine alpha chain, are both active in this assay. Note that in this assay, cycling levels for cells treated with pINPROL occasionally have negative numbers, indicating that there are even more colonies in the Ara C treated pool than in the non-treated pool.

As described in Example 2, pINPROL inhibits the proliferation of the murine stem cell line FDCP-MIX in a tritiated thymidine uptake assay. Figure 20 demonstrates that purified hemoglobin alpha or beta chains are both active in this assay, with inhibitions seen at < 2ng/ml.

The foregoing provides evidence that the beta chain of porcine hemoglobin exhibits INPROL activity. Other data (e.g., Table 9, Fig. 20) demonstrate that isolated alpha chain, as well as intact hemoglobin, are also active as stem cell inhibitors. Active preparations also include mixtures of alpha and beta chains (e.g., Fig. 5).

The observations that isolated alpha globin chain and/or isolated beta globin chain are active indicate that the activities described here do not require an intact three-dimensional hemoglobin structure. Fragments of alpha and beta chain are also active as stem cell inhibitors and stimulators.

Table 8

Treatment	% Kill
NBM[1]	15
TPBM[2]	36
pINPROL 200 ng/ml	23
40 ng/ml	0
Hbg[3] 200 ng/ml	25
40 ng/ml	7
MIP-1α 200 ng/ml	13

[1]NBM = Normal Bone Marrow
[2]TPBM = Bone marrow from testosterone-treated mice
[3]Hbg = C_4 Reverse-phase purified porcine hemoglobin beta chain (derived from 2X crystallized pig hemoglobin)

Table 9

Treatment	% Kill
Control[1]	43
Porcine alpha chain[2]	- 4
Porcine beta chain[2]	- 14

[1]Control - Bone marrow from Balb/c mice
[2]100 ng/ml (Purified as in Fig. 21)

Example 15: Purified INPROL, Purified Porcine Alpha Hemoglobin or Purified Porcine Beta Hemoglobin are Active *In Vivo*

In order to test the ability of purified porcine hemoglobin chains to act *in vivo*, BDF_1 mice were injected with testosterone propionate as described in Example 1. Twenty four hours later, mice received 500 ng of either pINPROL, porcine hemoglobin alpha chain (purified from peripheral red blood cells as in Fig. 21), porcine beta chain (purified from peripheral red blood cells as in Fig. 21) or the equivalent volume of carrier intravenously. Forty eight hours later the bone marrow from each mouse was harvested and the CFU-MIX assay conducted as described in Example 14. As shown in Table 10, pINPROL, pig alpha chain and pig beta chain all were active *in vivo* , reducing the per cent of CFU-MIX in cycle to basal levels.

Table 10

Treatment	% Kill
Control[1]	45
pINPROL[2]	5
Porcine alpha chain[2]	5
Porcine beta chain[2]	- 5
Basal[3]	4

[1]Control - Bone marrow from testosterone-treated BDF_1 mice
[2]100 ng/ml
[3] Basal - Bone marrow from untreated BDF_1 mice

Example 16: Purified Human Hemoglobin Alpha Chain, Biotinylated Human Hemoglobin Alpha Chain, Biotinylated Human Hemoglobin Beta Chain, Human Hemoglobin Gamma Chain and Human Hemoglobin Delta Chain All Exhibit Stem Cell Inhibitory Activity *In Vitro*

Human hemoglobin was obtained either from Sigma Chemical Corporation or was isolated by standard means from adult human peripheral blood or umbilical cord blood. Individual chains were isolated by reversed-phase HPLC in a similar manner as that described above for porcine alpha and beta chains (see B. Masala and L. Manca, Methods in Enzymology vol. 231 pp. 21-44, 1994). Purified alpha, beta, gamma and delta chains were obtained. For biotinylated alpha and beta chains, 1 mg of adult human hemoglobin was treated with 37 µg of NHS LC Biotin (Pierce) and the chains separated by reverse phase chromatography as above.

As shown in Tables 11, 12 and 13, purified human alpha, biotinylated human alpha, biotinylated human beta, human gamma and human delta hemoglobin chains are all active in the CFU-MIX cycling assay.

Table 11

Treatment	% Kill
Control[1]	49
Human alpha chain[2]	- 1
Human beta chain[2]	41
Human gamma chain[2]	- 63

[1]Control - Bone marrow from Balb/c mice
[2]100 ng/ml

Table 12

Treatment	% Kill
Control[1]	47
Human gamma chain[2]	12
Human delta chain[2]	- 4

[1]Control - Bone marrow from Balb/c mice
[2]100 ng/ml

Table 13

Treatment	% Kill
Control[1]	68
Human alpha chain[2]	19
Biotinylated alpha chain[2]	7
Human beta chain[2]	55
Biotinylated beta chain[2]	25

[1]Control - Bone marrow from Balb/c mice
[2]100 ng/ml

Example 17: Purified Human Alpha Chain, Alpha-Beta Dimer or Hemoglobin are Active In Vivo

Purified human alpha chain, alpha-beta dimer or hemoglobin were tested in an *in vivo* assay as described in Example 15. As shown in Table 14, each of these were active at a concentration of 500 ng/mouse.

Table 14

Treatment	% Kill
Control[1]	49
Human alpha chain	- 22
Human alpha-beta dimer	14
Human hemoglobin	- 31

[1]Control - Bone marrow from testosterone-treated BDF_1 mice

Example 18: Porcine INPROL is Active on Human Mononuclear or $CD34^+$ Cord Blood Cells *In Vitro*

In order to investigate the ability of purified INPROL from porcine bone marrow to affect cycling on human progenitors, umbilical cord blood cells were obtained. Either the total mononuclear cell fraction obtained after separation on Ficoll or the $CD34^+$ fraction obtained after fractionation on anti-CD34 affinity columns (CellPro Inc.) was used. Cells were incubated for 48 hours *in vitro* in the presence of interleukin 3 (IL-3) and stem cell factor (SCF) (100 ng/ml each) in order to ensure that the early stem cells were in cycle. After this preincubation, cycling assays were conducted as described in Example 14 for the mouse except that CFU-GEMM (instead of CFU-MIX) were counted

on Day 18 after plating. As shown in Table 15, porcine INPROL inhibited cycling of CFU-GEMM in either the bulk mononuclear cells or in the $CD34^+$ fraction.

Table 15

	Treatment	% Kill
Mononuclear Cells		
	Control	93
	pINPROL[1]	16
$CD34^+$Cells		
	Control	41
	pINPROL[1]	21

[1] 100 ng/ml

Example 19: Purified Human Alpha Hemoglobin is Active on Human CFU-GEMM

Human umbilical cord blood mononuclear cells were obtained and incubated in IL-3 and SCF and used in a cycling assay as described in Example 18. As shown in Table 16, both porcine INPROL purified from bone marrow and human alpha hemoglobin, purified from peripheral blood, were active in this assay.

Table 16

Treatment	% Kill
Control	100
pINPROL[1]	- 6
Human alpha chain[1]	- 23

[1] 100 ng/ml

Example 20: Peptides obtained from Human Alpha Hemoglobin and from Human Beta Hemoglobin Sequences are Active

To identify active peptide sequences, the three dimensional structure of myoglobin (which is inactive in this assay) was superimposed on the native three dimensional structure of the alpha chain present in adult human hemoglobin using a computer modeling program. Two peptides (representing amino acids 43-55 and 64-82, which are regions which are structurally different from myoglobin in three-dimensional space) were identified as having activity in the CFU-MIX cycling assay. In order to more closely approximate the loop found in the native alpha chain, a cyclic derivative of the 43-55 peptide (c43-55) (utilizing a disulfide bond) was also synthesized and found to be active.

The sequence of these peptides is as follows:

43-55 Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val

("Peptide 43-55")

c(43-55) Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys

(where the two Cys residues are disulfide-bonded) ("Cyclic Peptide 43-55")

64-82 Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala ("Peptide 64-82")

Two hemorphin sequences, hemorphin 10 (amino acids 32-41 of the beta chain sequence) and hemorphin 7 (amino acids 33-40) were tested and found to be active.

The sequences are as follows:

Hemorphin 10 Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln-Arg-Phe

Hemorphin 7 Val-Val-Tyr-Pro-Trp-Thr-Gln-Arg

To test the activity of these sequences, the CFU-MIX cycling assay was conducted as described in Example 14. As shown in Tables 17-19, these peptides all are active in this assay.

Table 17

Treatment	% Kill
Control	47
pINPROL[1]	0
Peptide (43-55)	
100 ng/ml	2
10 ng/ml	18
1 ng/ml	11

[1]100 ng/ml

Table 18

Treatment	% Kill
Control	43
Peptide (43-55)[1]	5
Peptide (64-82)[1]	9
Hemorphin 10[1]	1
Hemorphin 7[1]	0

[1]All peptides tested at 100 ng/ml

Table 19

Treatment	% Kill
Control	47
Cyclic Peptide 43-55[1]	0

[1]Tested at 100 ng/ml

Example 21: A Peptide Fragment Obtained from Human Alpha Hemoglobin by Formic Acid Cleavage is Active

Human alpha hemoglobin chain has a formic acid cleavage site between amino acid positions 94 and 95 (Asp-Pro). Cleavage was obtained by incubating purified human alpha chain (as in Example 16) at a concentration of 1 mg/ml in 70% formic acid for 72 hours at 37°C. The 1-94 fragment was purified from the uncleaved alpha chain and the 95-141 fragment by reverse-phase HPLC as in Example 16; fractions were followed using SDS-PAGE (as in Example 22). Identity of the purified 1-94 protein fragment was confirmed by electrospray ionization mass spectrometry.

To assess the stem cell inhibitory activity of this fragment, the CFU-MIX cycling assay is used as in Example 14:

Table 20

Treatment	% Kill
Control[1]	50
Human Alpha[2]	12
1-94 fragment[3]	0

[1] Balb/c bone marrow

[2] Purified, non-recombinant human alpha hemoglobin, as in Example 16 (100 ng/ml)

[3] Purified formic-acid cleaved protein, as in the present Example (100 ng/ml)

Example 22: Expression of Hemoglobin Alpha Chain, Polypeptide 1-141, Polypeptide 1-97, Peptide 43-55 and Peptide c(43-55) in *E. coli* as Ubiquitin Fusions

Genes for peptides 43-55 ("p13") and c43-55 ("p15") (as in Example 20) were synthesized by annealing the corresponding oligonucleotides according to the optimal *E. coli* codon usage (Anderssen and Kurland, Micro. Reviews 54:198-210, 1990). The gene for the intact human alpha hemoglobin chain ("p141") was obtained by designing a set of oligos to PCR amplify from a human bone marrow cDNA pool (Clontech, Palo Alto, CA). The gene for the 1-97 fragment ("p1-97") was obtained by PCR amplification of the plasmid containing the p141 gene after appropriate subcloning.

The above genes were expressed as ubiquitin fusion proteins (see US Patents 5,132,213; 5,196,321 and 5,391,490 and PCT WO 91/17245). The host strain, *E. coli* DH5αF'IQ (Life Technologies, Inc., Gaithersburg, MD) was transformed with the ubiquitin expression vector, pDSUb, containing the appropriately synthesized gene (above). pDSUb is a derivative of pDS78/RBSII that expresses human ubiquitin (Fig. 22A) (Hochuli *et al.*, Biotechnology 6:1321-5, 1988). Loetscher *et al.* (JBC 266:11213-11220, 1991) modified pDS78/RBSII by excising the chloramphenicol acetyl transferase (CAT) sequences from the Hochuli plasmid and religating the plasmid (Fig. 22B). A synthetic ubiquitin gene was constructed by pairwise annealing of kinased synthetic oligonucleotides encoding human ubiquitin with codon usage optimized for bacterial expression. pDSUb was then constructed by inserting the synthetic ubiquitin gene,

comprised of assembled oligonucleotides, into a Klenow blunted *Bam H1-Bgl II* digest of the derivatized pDS78/RBSII. The resulting plasmid, pDSUb (Fig. 22C), was shown to express ubiquitin at a high level in *E. coli.*

The plasmid containing p97 and the one containing p141 were constructed by inserting *Afl* II -*Pst* I digested PCR products encoding the p97 or p141 protein and fusion junction, in a directional cloning, into pDSUb that had been digested with *Afl* II and *Pst* I. Similarly, the plasmid containing p13 and the one containing p15 were constructed by inserting kinased and annealed oligonucleotides, bearing the appropriate sticky ends and encoding the peptide and fusion junction, into *Afl* II -*Pst* I digested pDSUb.

Transformants were selected with 100 μg/ml ampicillin, 5 μg/ml neomycin, with colonies appearing after two days at 30°C. Transformants were screened by PCR across the insertion site. Colonies containing the correctly sized insert were then screened for expression of a fusion protein of the appropriate size by SDS-PAGE (see below). The ubiquitin fusion was overexpressed by the addition of IPTG which titrates the lac repressor, removing it from the promoter of pDSUb (DH5αF'IQ contains an upregulated lacI^q gene on the F' factor which is selected with 10 μg/ml neomycin.)

Plasmid DNA from clones that exhibited an overexpressed, induced ubiquitin fusion protein was prepared and sequenced by the dideoxy method using the Sequenase Version 2.0 kit (United States Biochemical.) Positive clones were then frozen down and stored in glycerol at -80°C. Positive clones were maintained on LB plates containing ampicillin (100 μg/ml), neomycin (10 μg/ml) and 1% glucose, at 30°C. They were streaked weekly for up to 10 passages, after which a fresh streak was taken from a frozen seed vial for serial culture, to insure strain authenticity.

To obtain protein for assay, 100 ml starter cultures in 250 ml shake flasks were grown from single colonies by overnight incubation (16-20 hours) in 2xYT medium with ampicillin (100 μg/ml), neomycin (10 μg/ml) and 1% glucose. Shaker flask cultures were maintained at 30° C and 250 rpm in a New Brunswick environmental shaker incubator.

The next morning the culture was diluted to 1liter with medium. Cells were induced by IPTG addition to 1 mM (final dilution) at OD_{600} = 0.5 and harvested at OD_{600}=0.8 by centrifugation. The harvested cells were resuspended in hypotonic lysis buffer (100 µl of 50mM Tris, pH 10.0). The bacterial cells were lysed by subjecting the suspension to three cycles of freeze-thaw (dry ice-ethanol bath for freezing and 60°C for thawing). The suspension was then sonicated for 10 min and centrifuged at 12,000g for 10 min. The resulting supernatant was designated as "S1". The cell pellet was resuspended in 50 mM Tris, pH10 and 2x SDS tricine loading buffer (Novex, San Diego, CA) (1:1). The mixture was then heated at 95°C for 15 min and centrifuged at 12,000g for 10 min. The portion of the precipitate capable of being resolubilized in this manner was called "P1". The portion of the precipitate derived from the remaining pellet was called "P2". P2 was resuspended in loading buffer as for P1. Samples from S1, P1 and P2 were analyzed by SDS-PAGE.

SDS-PAGE gels were run using a two buffer tricine system in a minigel apparatus, with 10-20% tricine gels (Novex). Anode (bottom) buffer was 0.2 M Tris, pH 9.0. Cathode (top) buffer was 0.1 M Tris, 0.1 M Tricine, 0.1% SDS, pH 8.25. A commercial molecular weight marker, "Multi-Mark" (Novex) was used. Bovine ubiquitin, used as a standard, was purchased from Sigma. Gels were run at a constant current of 4 mA until the dye marker reached the bottom of the gel. Gels were stained with 0.25% Coomassie Blue R250 (Sigma) in acetic acid:methanol (10%:40%) and destained in the same solution minus the dye.

The majority (> 70%) of the intact p141-ubiquitin fusion protein was found in the precipitate (P_1 and P_2) after centrifugation of the bacterial lysate. In sharp contrast, the majority (> 70%) of the p97-ubiquitin fusion protein was found in the soluble fraction (S_1). This confirmed that the removal of the C-terminal hydrophobic region resulted in a product with improved solubility characteristics. Similarly, the p13 and p15 peptides were also contained in the soluble fraction.

The UCH-L3 ubiquinase enzyme (Recksteiner, M. (Ed.) Ubiquitin, Plenum Press (NY) 1988; Wilkinson *et al.*, Science 246:670-73, 1989) was expressed in pRSET (Invitrogen, San Diego, CA) which was used to transform the host strain BL21/DE3. UCH-L3 is a ubiquitin-specific protease that cleaves at the ubiquitin C-terminal extension. It was partially purified from bacterial lysates by a 35% (w/v) ammonium sulfate precipitation. The exact percentage of ammonium sulfate used was monitored by SDS-PAGE for the presence of a 25.5 kD band. The supernatant was dialyzed against 50mM Tris, pH 7.4, and assayed against a ubiquitin peptide fusion substrate. The active supernatant was aliquoted and frozen at -20°C. A typical reaction mixture contains 3 µl lysate, 1µl 1M DTT, 1µl UCH-L3 (as above) and 5 µl reaction buffer (50 mM Tris, pH 7.4). The reaction was carried out at room temperature for 20 min. For large scale digestion, 300 µl lysate was mixed with 100 µl 1M DTT, 20 µl UCH-L3 and 580 µl reaction buffer.

Peptides or proteins contained in the soluble (S_1) fraction were further purified by reverse phase HPLC as in Example 16; fractions were monitored by SDS-PAGE and their identity confirmed by electrospray ionization mass spectrometry (see below). The purified peptides or proteins were enzymatically digested by UCH-L3 as above, resulting in a non-ubiquinated final product. This cleaved material was then re-purified by reverse phase HPLC. Purification was followed by SDS-PAGE and the identity of the final product confirmed by electropray ionization mass spectrometry.

An alternative to the *in vitro* cleavage with UCH-L3 as described above is to co-express a ubiquitin cleaving enzyme in the same bacteria as the desired ubiquitin fusion. For this purpose, a vector (pJT184) expressing the ubiquinase UBP1 (Tobias and Varshavsky, JBC 266:12021-12028, 1991) was used. Bacteria co-expressing p97 ubiquitin fusion and UBP1 exhibited complete digestion of the fusion protein *in vivo*; bacteria co-expressing p141 ubiquitin fusion and UBP1 exhibited partial (approximately

70%) digestion of the fusion protein. The *in vivo* digested p97 protein was purified by ammonium sulfate precipitation followed by reverse-phase HPLC as above.

To confirm the identity of the expressed and purified polypeptides, electrospray ionization mass spectrometry was performed using a VG Biotech BIO-Q instrument with quadrupole analyser. Myoglobin was used to calibrate the instrument. The major component obtained with purified p97 was a single peak of molecular weight of 10,339 daltons; this compares favorably with the calculated molecular weight of 10,347, confirming the identity of the recombinant p97 fragment.

Example 23: Recombinant p1-97 Retains Stem Cell Inhibitory Activity

To assess the bioactivity of recombinant p1-97, the CFU-GEMM cycling assay was used as in Example 18:

Table 21

Treatment	% Kill
Control[1]	62
Human Alpha[2]	11
p97[3]	0

[1] Human bone marrow mononuclear cells
[2] Purified, non-recombinant human alpha hemoglobin, as in Example 16 (100 ng/ml)
[3] Purified recombinant p97, as in Example 22 (100 ng/ml)

Example 24: Human Alpha Hemoglobin and Peptide 43-55 Inhibit CFU-MIX Cycling *In Vivo* in Testosterone or 5-Fluorouracil (5FU) Treated Mice

To assess the stem cell inhibitory activity of peptide 43-55 *in vivo*, B6D2 F_1 mice were pre-treated with testosterone propionate as described in Example 1 or with 5FU. Specifically, testosterone propionate (100 mg/kg body weight) was injected i.p. on Day 0 into mice. Alternatively, mice were injected on Day 0 with 5FU (200 µg/kg body weight).

24 hours later (Day 1), varying doses of peptide 43-55 or vehicle were injected i.v. Bone marrow was harvested on Day 2 and the CFU-MIX cycling assay conducted as in Example 14. Specifically, mice were sacrificed and single cell bone marrow suspensions prepared from the femurs. The cells were washed once and the concentration adjusted to 5 x 10^6 cells/ml in Fischer medium. For each test condition, one milliliter of cells was added to each of two polypropylene tubes. The tubes were incubated at 37°C for 3 hours without ("Control") or with ("Experimental") the appropriate concentration of test substance. At the end of the incubation, 30 µg/ml of cytosine arabinoside ("Ara C" (Sigma)) was added to half of the tubes and the same volume of Fischer's medium was added to the others. The tubes were incubated for a further 1 hour at 37°C, after which they were placed on ice and washed twice with cold Fischer medium.

The cells were readjusted to 5 x 10^4 - 10^6/ml in Fischer's medium and 0.5 ml of cell suspension added to 5 ml of Methocult M3430 methylcellulose medium (Stem Cell Technologies, Vancouver, British Columbia). The mixture was vigorously mixed with a vortex and 1 ml was dispensed into each of five 35mm dishes. The 35mm dishes were in turn placed in a covered 150 mm dish with one open 35mm dish containing sterile water. CFU-MIX colonies were counted with the use of an inverted microscope after 7 days of incubation at 37°C.

Differences in colony number between the tubes treated with medium versus the tubes treated with Ara C represent the percentage of cells in cycle under that condition according to the formula:

$$\%S = \frac{a-b}{a} \times 100\%$$

where a = Number of CFU-MIX from tube incubated with medium alone

b = Number of CFU-MIX from tube incubated with Ara C

Table 22[1]

Treatment	% Kill
Control	35
Human Alpha Chain (500 ng)[2]	13
Peptide 43-55 (0.5 ng)[2]	0

[1] Testosterone-pretreated animals

[2] Amount injected i.v. per 20 gram mouse

Table 23[1]

Treatment	% Kill
Control	62
Human Alpha Chain (500 ng)[2]	0
Peptide 43-55 (0.5 ng)[2]	3
Cyclic Peptide 43-55 (0.5 ng)[2]	14

[1] 5FU-pretreated animals

[2] Amount injected i.v. per 20 gram mouse

Example 25: Peptide 43-55 Is Active As a Stem Cell Inhibitor when Biotinylated at the N-terminal Phe (Phe43) or Iodinated at Phe 43 or Phe46

Peptide 43-55 was synthesized by solid phase peptide synthetic techniques (American Peptide Co., Sunnyvale, CA). Peptide analogs were synthesized with iodine at the *para* position of Phe43 or of Phe46. Biotinylated Peptide 43-55 was synthesized by linking the COOH of biotin with a C_4 carbon linker to the N-terminal NH_2 of Phe43.

Table 24

Treatment	% Kill
Control	31
Peptide 43-55 (1 ng/ml)	8
Biotinylated peptide 43-55 (1 ng/ml)	15

Example 26: Morphine Inhibits Cycling of Murine CFU-MIX *In Vitro*

Morphine was tested in the CFU-MIX cycling assay using bone marrow from Balb/c mice as in Example 24:

Table 25

Treatment	% Kill
Control	44
Human Alpha Chain (100 ng/ml)	0
Morphine (10^{-7} M)	10
(10^{-9} M)	15
(10^{-11} M)	32

Example 27: The Opiate Peptides DAMGO and DALDA Inhibit Cycling of Murine CFU-MIX*In Vitro*

DAMGO and DALDA were tested in the CFU-MIX cycling assay using bone marrow from Balb/c mice as in Example 24:

Table 26

Treatment	% Kill
Control	33

DAMGO (10^{-5} M)	15
(10^{-7} M)	0
(10^{-9} M)	38
DALDA (10^{-5} M)	47
(10^{-7} M)	0
(10^{-9} M)	34

Example 28: Nociceptin Inhibits Cycling of Murine CFU-MIX *In Vitro*

Nociceptin was tested in the CFU-MIX cycling assay using bone marrow from Balb/c mice as in Example 24:

Table 27

Treatment		% Kill
Control		31
Peptide 43-55 (1 ng/ml)		8
Nociceptin	(10^{-7} M)	6
	(10^{-9} M)	0

Example 29: Naloxone Antagonizes the Inhibitory Activity of Human Alpha and Delta Hemoglobin Chains, Hemorphin 10 and Peptide 43-55

The CFU-MIX cycling assay was conducted as in Example 24. Test substances were assayed by themselves or in the presence of naloxone (10^{-5} - 10^{-7}M). Naloxone itself had no effect on the assay at these concentrations.

Table 28

Treatment	% Kill
Control	38
Naloxone[1]	36
Human Alpha (100 ng/ml)	0
" + Naloxone[1]	52
Peptide 43-55 (10 ng/ml)	6
" + Naloxone[1]	50
Hemorphin 10 (100 ng/ml)	0
" + Naloxone[1]	36

[1] Used at 10^{-5} M final concentration

Table 29

Treatment	% Kill
Control	32
Human Delta (100 ng/ml)	10
" + Naloxone[1]	31

[1] Used at 10^{-7} M final concentration

Example 30: Low Concentrations of Naloxone Inhibit Cycling of Murine CFU-MIX

The CFU-MIX assay was conducted as in Example 24.

Table 30

Treatment	% Kill
Control	38
Human Alpha (100 ng/ml)	0
Naloxone (10^{-10} M)	0

Example 31: The mu Opiate Receptor Antagonist CTOP Antagonizes the Inhibitory Activity of Human Hemoglobin Alpha Chain, Peptide 43-55 and Peptide 64-82

CTOP (H-D-Phe-Cys-Tyr-D-Trp-Orn-Thr-Pen-Thr-NH_2, with a disulfide between Cys_2 and Pen_7) is an analog of somatostatin which is a mu opiate receptor specific antagonist. Test substances were assayed by themselves or in the presence of CTOP (10^{-7} M). CTOP itself had no effect on the assay at this concentration but antagonized the cell cycle inhibition caused by alpha hemoglobin or peptide 43-55.

Table 31

Treatment	% Kill
Control	42
CTOP[1]	36
Human Alpha (100 ng/ml)	0
" + CTOP[1]	20
Peptide 43-55 (10 ng/ml)	8
" + CTOP[1]	21

[1] Used at 10^{-7} M, final concentration

Example 32: Pretreatment with Human Alpha Chain Increases the Number of Late-Forming Cobblestone-Forming Cells

The cobblestone assay was conducted as described by Ploemacher and colleagues (Ploemacher *et al.*, Blood 74:2755-63, 1989; van der Sluijs *et al.*, Exp. Hematol. 18:893-6, 1990; Ploemacher *et al.*, Blood 78:2527-33, 1991; Ploemacher *et al.*, J. Tiss. Cult. Meth. 13:63-68, 1991; Down and Ploemacher, Exp. Hematol. 21:213-21, 1993). The cobblestone assay measures the appearance of groups of cells (or "cobblestones") within a monolayer of stromal cells. Very primitive stem cells will not form colonies in soft agar but do form cobblestones in the presence of a stromal monolayer. The cells which form cobblestones are referred to as "cobblestone area forming cells" (CAFC). The more differentiated (e.g., GM-CFC) progenitors form transient cobblestones which appear and then disappear within the first few weeks of culture whereas more primitive stem cells (e.g., long-term repopulating cells) form cobblestones which appear only after 4-5 weeks of culture. Thus, CAFC forming on days 7-14 of culture are enriched in CFU-GM, CAFC forming on days 28-35 are enriched in CFU-MIX, and CAFC forming on days 28-35 are enriched in long-term repopulating cells.

B6D2F1 mice were treated with testosterone propionate as in Example 24. The next day bone marrow was removed and incubated for 4 hours with or without human alpha hemoglobin chain (100 ng/10^6 cells) after which they were plated in a cobblestone assay. The assay used consists of limiting dilution long term bone marrow cultures (LTBMC) in 96-well plates. The cultures were prepared by growing the FBMD-1 murine stromal cell line (Breems *et al.*, Leukemia 11:142-50, 1997) until confluent; 96-well plates plates with confluent monolayers were stored at 33°C until assay. Murine bone marrow cells were prepared as a single cell suspension and the following dilutions of cells were plated per well in 0.2 ml of LTBMC medium (Stem Cell Technologies, Vancouver): 27,000; 9000;

3000;1000; 333. Twenty wells were plated for each dilution per condition and distributed over two plates.

The frequency of cobblestone area forming cells (CAFC) was calculated as previously described (Ploemacher *et al.*, Blood 78:2527-33, 1991; Ploemacher *et al.*, J. Tiss. Cult. Meth. 13:63-68, 1991; Breems *et al.*, Leukemia 8:1095-104, 1994). The results are shown in Figure 23. Preincubation of cycling stem cells with human alpha hemoglobin chain increased the proportion of late-forming CAFC by approximately 5-fold. Treatment of non-cycling stem cells with alpha chain had no effect.

Example 33: Human Alpha Hemoglobin and Peptides 43-55, Cyclic 43-55 and 64-82 Inhibit Cycling of Human Cord Blood CFU-GEMM

The human cord blood CFU-GEMM cycling assay was conducted as in Example 19. Specifically, mononuclear cells were isolated from human umbilical cord blood cells and adjusted to 2-4 x 10^4 cells/ml in IMDM tissue culture medium supplemented with 10% FBS, 100 ng/ml kit ligand and 100 ng/ml human IL-3. The cells were incubated for 48 hours at 37°C.

After incubation, cells were washed and resuspended in serum-free IMDM at a concentration of 10^6 cells/ml. One ml of cells was added to each of two polypropylene tubes per condition and the cycling assay conducted as in Example 24 for mouse bone marrow. After the Ara C incubation cells were washed with cold IMDM and adjusted to 10,000 to 20,000 cells per 0.5 ml IMDM and mixed with 5 ml Methocult H4433 (Stem Cell Technologies). Alternatively, Methocult H4435 methylcellulose medium (Stem Cell Technologies) was used in which case the cell concentration was adjusted to 2500-5000 cells per 0.5 ml IMDM. The cells were plated as in Example 24 and CFU-GEMM colonies scored on days 14-18.

Table 32

Treatment	% Kill
Control	52
Human Alpha Chain (100 ng/ml)	0
Peptide 43-55 (1 ng/ml)	20
(10 ng)	12
(100 ng)	5
Cyclic Peptide 43-55 (1 ng/ml)	32
(10 ng)	0
(100 ng)	11
Peptide 64-82 (1 ng/ml)	21
(10 ng)	20
(100 ng)	39

Example 34: Human Alpha Hemoglobin and Peptide 43-55 Inhibits Cycling of Adult Human Bone Marrow CFU-GEMM

$CD34^+$ stem cells were obtained from Poietic Technologies (Gaithersburg, MD) after purification from human bone marrow by means of a CellPro column. Cells were incubated for 48 hours with kit ligand and IL-3 and used in a CFU-GEMM cycling assay in Example 26.

Table 33

Treatment	% Kill
Control	47
Human Alpha Chain (ng/ml)	0
Peptide 43-55 (ng/ml)	0

Example 35: CFU-GEMM in Mobilized Human Peripheral Blood Actively Cycle and are Inhibitable by Human Alpha Hemoglobin, Peptide 43-55, DAMGO or Morphine

Peripheral blood was obtained from breast cancer patients undergoing peripheral stem cell mobilization with cyclophosphamide and G-CSF according to standard protocols. Red blood cells were removed with Ficoll Hypaque (cells were diluted 1:1 with IMDM and 20 ml layered on top of 16 ml Ficoll and centrifuged at 800 g for 30 minutes; mononuclear cells were removed from the interphase and washed twice in IMDM). In one case mononuclear cells were stored frozen in liquid nitrogen before assay. The

mononuclear cells were plated for the CFU-GEMM cycling assay as in Example 26 except that 2.5 - 5 x 10^5 cells were plated per dish.

Table 34

Treatment	% Kill
Control (Patient #1)	48
Human Alpha Chain (100 ng/ml)	0

Table 35

Treatment		% Kill
Control (Patient #2)[1]		67
Human Alpha Chain (ng/ml)		2
Peptide 43-55 (10 ng/ml)		0
Morphine	(10^{-7} M)	24
"	(10^{-9} M)	0
DAMGO	(10^{-7} M)	15
"	(10^{-9} M)	0

Table 36

Treatment	% Kill
Control (Patient #3)[1]	29
Peptide 43-55 (0.1 ng/ml)	23
" (1.0 ng/ml)	0
" (10 ng/ml)	15

[1] From cells stored frozen before assay

Example 36: High Doses of Human Alpha or Beta Hemoglobin, Myoglobin, Peptide 1-97, Peptide 43-55, Peptide 64-82 Nociceptin or DALDA Stimulate Cycling of Quiescent Murine Stem Cells

Microgram per milliliter doses of hemoglobin chains, myoglobin and peptides were assayed for stimulation of quiescent stem cells. Bone marrow was obtained from untreated $B6D2F_1$ tested in the CFU-MIX cycling assay as in Example 24. Stem cells isolated from untreated $B6D2F_1$ mice are normally slowly cycling unless stimulated (e.g. by testosterone propionate (cf. Example 1) or chemotherapy such as 5FU (cf. Example 4)) to enter into cycle.

Table 37

Treatment	% Kill
Control	3
Human α Chain (1 μg/ml)	0
(10 μg/ml)	24
(100 μg/ml)	40

Table 38

Treatment	% Kill
Control	9
Human β Chain (μg/ml)	55
Human Myoglobin (μg/ml)	30

Table 39

Treatment	% Kill
Control	3
Human α Chain (100 μg/ml)	41
DALDA (10^{-5} M)	24
(10^{-3} M)	41
DADLE (10^{-5} M)	0
(10^{-3} M)	0

Table 40

Treatment	% Kill
Control	0
Human α Chain (100 μg/ml)	30
Peptide 43-55 (10 μg/ml)	26

Table 41

Treatment	% Kill
Control	16
Peptide 1-97 (10 μg/ml)	62
" (10 μg/ml)	41

Table 42

Treatment	% Kill
Control	4
Peptide 64-82 (1 μg/ml)	25
Nociceptin (10^{-5} M)	36

Example 37: Intravenous Administration of High Dose Human Alpha Hemoglobin Stimulates Cycling of Quiescent Murine Stem Cells

Human alpha hemoglobin was injected i.v. into untreated B6D2F$_1$ mice. 24 hours later, the mice were sacrificed, bone marrow collected from femurs and the CFU-MIX assay conducted as in Example 24.

Table 43

Treatment	% Kill
Control (Untreated)	0
Medium (Injection Control)	0
Human α Chain (150 μg/mouse)	48

Example 38: Naloxone Antagonizes the Stem Cell Stimulatory Activity of High Dose Human Alpha Hemoglobin, Peptide 43-55

Table 44

Treatment	% Kill
Control	6
Human Alpha Chain (100 ng/ml)	48
" + Naloxone[1]	0

[1] Used at 10^{-7} M final concentration

* * *

While the present invention has been described in terms of preferred embodiments, it is understood that variations and modifications will occur to those skilled in the art. Therefore, it is intended that the appended claims cover all such equivalent variations which come within the scope of the invention as claimed.

WHAT IS CLAIMED IS:

1. A polypeptide comprising hemoglobin alpha chain wherein the C-terminal hydrophobic domain has been substituted or deleted.

2. A polypeptide comprising hemoglobin alpha chain wherein the C-terminal haptoglobin-binding domain has been substituted or deleted.

3. A polypeptide comprising amino acids 1-97 of the human alpha hemoglobin chain.

4. A pharmaceutical composition comprising (a) a polypeptide as in claim 1 or 2 and (b) a pharmaceutically acceptable carrier.

5. A pharmaceutical composition comprising a polypeptide consisting of amino acids 1-97 of the human alpha hemoglobin chain and a pharmaceutically acceptable carrier.

6. A pharmaceutical composition comprising a polypeptide consisting of amino acids 1-94 of the human alpha hemoglobin chain and a pharmaceutically acceptable carrier.

7. A pharmaceutical composition as in claim 4-6 in unit dosage form.

8. A pharmaceutical composition as in claim 7 comprising 0.1 mgs. to 6 gms. of one or two compounds selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

9. A method of inhibiting stem cell proliferation comprising contacting hematopoietic cells with a stem cell proliferation inhibiting amount of a polypeptide as in claim 1 or 2.

10. A method as in claim 9 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain, a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain and a peptide having the sequence Phe-Leu-Gly-Phe-Pro-Thr.

11. A method of stimulating the growth of B cells which comprises contacting hematopoietic cells with a growth stimulating amount of a polypeptide as in claim 1 or 2.

12. A method of treating cancer in a mammal suffering therefrom comprising the steps of:

a) administering radiotherapy or chemotherapy, and

b) administering a stem cell proliferation inhibiting amount of a polypeptide as in claim 1 or 2.

13. A method as in claim 12 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

14. A method as in claim 12 wherein steps a and b are repeated one or more times.

15. A method as in claim 12 wherein step a is conducted after step b.

16. A method as in claim 12 wherein step b is conducted within 24 hours before or after

step a.

17. A method for treating cancer in a mammal comprising:

a) removing hematopoietic cells from said mammal,

b) treating said hematopoietic cells *ex vivo* with a polypeptide as in claim 1 or 2,

c) treating said hematopoietic cells of step b with chemotherapy or radiation,

d) performing myeloablative treatment on said mammal, and

e) transplanting into said mammal the hematopoietic cells of step c.

18. A method as in claim 17 wherein said polypeptide in step (b) is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

19. A method of inhibiting stem cell division in a mammal exposed to an agent which damages or destroys stem cells comprising administering a stem cell proliferation inhibiting amount of a polypeptide as in claim 1 or 2.

20. A method as in claim 19 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain, a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain and a peptide having the sequence Phe-Leu-Gly-Phe-Pro-Thr.

21. A method as in claim 19 wherein said agent is an antiviral agent.

22. A method of maintaining mammalian hematopoietic stem cells *ex vivo* comprising contacting hematopoietic cells with a stem cell proliferation inhibiting amount of a polypeptide as in claim 1 or 2.

23. A method as in claim 22 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain, a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain chain, and a peptide having the sequence Phe-Leu-Gly-Phe-Pro-Thr.

24. A method as in claim 22 wherein said hematopoietic cells are selected from the group consisting of bone marrow cells, peripheral blood cells, mobilized peripheral blood cells, fetal liver and umbilical cord blood cells.

25. A method of treating a myeloproliferative or autoimmune disease or epithelial stem cell hyperproliferation in a mammal suffering therefrom comprising administering a hyperproliferative reducing amount of a polypeptide as in claim 1 or 2.

26. A method as in claim 25 wherein said myeloproliferative disease is a myelodysplastic syndrome.

27. A method for differentially protecting normal stem cells and not cancer cells in a mammal from chemotherapy or radiation comprising administering a stem cell protecting amount of a polypeptide as in claim 1 or 2.

28. A method as in claim 27 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain, a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain, and a peptide having the sequence Phe-Leu-Gly-Phe-Pro-Thr.

29. A method as in claim 27 wherein said polypeptide is administered after said normal stem cells are induced to proliferate by exposure to a cytotoxic drug or radiation.

30. A method of vaccinating a mammal comprising administering a polypeptide as in claim 1 or 2 as an adjuvant before, during or after administration of a vaccine.

31. A method of treating a mammal having immunodepression caused by stem cell hyperproliferation comprising administering to said mammal an hyperproliferation reversing amount of a polypeptide as in claim 1 or 2.

32. A method of conducting gene therapy in a mammal comprising:

a) removing hematopoietic cells from said mammal,

b) transfecting said hematopoietic cells with a predetermined gene,

c) contacting said transfected hematopoietic cells *ex vivo* with a polypeptide as in claim 1 or 2

d) transplanting into said mammal the hematopoietic cells of step c.

33. A method as in claim 32 wherein said polypeptide in step (c) is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

34. A method as in claim 32 further comprising after step (a) treating said hematopoietic cells with at least one stimulatory cytokine to induce stem cell proliferation.

35. A method as in claim 32 further comprising after step (d) treating the mammal *in vivo* with said polypeptide.

36. A method for conducting *ex vivo* stem cell expansion comprising contacting hematopoietic cells with a polypeptide as in claim 1 or 2 and at least one stimulatory cytokine.

37. A method as in claim 36 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

38. A method as in claim 36 wherein said hematopoietic cells are cells selected from the group consisting of bone marrow cells, peripheral blood cells, mobilized peripheral blood cells, fetal liver and umbilical cord blood cells.

39. A pharmaceutical composition comprising (a) a polypeptide as in claim 1 or 2 and (b) at least one inhibitory compound selected from the group consisting of MIP-1α, TGFβ, TNFα, INFα, INFβ, INFγ, the pentapeptide pyroGlu-Glu-Asp-Cys-Lys, the tetrapeptide N-Acetyl-Ser-Asp-Lys-Pro, and the tripeptide glutathione (Gly-Cys-γGlu).

40. A method as in claim 39 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

41. A pharmaceutical composition comprising (a) a polypeptide as in claim 1 or 2 and (b) at least one stimulatory compound selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-9, IL-11, IL-13, IL-14, IL-15, G-CSF, GM-CSF, M-CSF, erythropoietin, thrombopoietin, stem cell factor, and flk2/flt3 ligand.

42. A method as in claim 41 wherein said polypeptide is selected from the group consisting of a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain and a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

43. A method for expressing alpha hemoglobin or substitution or deletion analogs thereof comprising expressing said alpha hemoglobin or substitution or deletion analogs as a ubiquitin fusion.

44. A method as in claim 43 wherein said expressing step is done in *E. coli*.

45. A method as in claim 43 wherein said expressing step includes expressing a ubiquitin cleaving enzyme.

46. A peptide having the sequence selected from the group consisting of biotin-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val, (iodo)Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val, Phe-Pro-His-(iodo)Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val and (iodo)Phe-Pro-His-(iodo)Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val.

47. A method of stimulating stem cell proliferation comprising con. hematopoietic cells with a stem cell proliferation stimulating amount of INPROL and/or opiate compound.

48. A method as in claim 47 wherein said INPROL is selected from the group consisting of the alpha chain of hemoglobin,the beta chain of hemoglobin,the gamma chain of hemoglobin, the delta chain of hemoglobin, the epsilon chain of hemoglobin, the zeta chain of hemoglobin,

a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain, and

a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain.

49. A method as in claim 47 wherein said INPROL is selected from the group consisting of peptides having the sequence:

Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,

Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys

(where the two Cys residues form a disulfide bond),

Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala,

Phe-Leu-Gly-Phe-Pro-Thr,

Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln-Arg-Phe,

Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln-Arg,

Leu-Val-Val-Tyr-Pro-Trp-Thr-Gln,

Leu-Val-Val-Tyr-Pro-Trp-Thr,

Leu-Val-Val-Tyr-Pro-Trp,

Leu-Val-Val-Tyr-Pro,

Val-Val-Tyr-Pro-Trp-Thr-Gln,

Tyr-Pro-Trp-Thr-Gln-Arg-Phe,

Tyr-Pro-Trp-Thr-Gln-Arg,

Tyr-Pro-Trp-Thr-Gln, and

Tyr-Pro-Trp-Thr.

50. A method as in claim 47 wherein said opiate compound is selected from the group consisting of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

51. A method of stimulating stem cell proliferation comprising contacting hematopoietic cells with a compound capable of binding opiate receptors.

52. A method as in claim 51 wherein said compound has selectivity for the mu subclass of opiate receptor.

53. A method of stimulating or inhibiting stem cell proliferation comprising contacting hematopoietic cells with a compound capable of binding nociceptin receptors.

54. A method of stimulating or inhibiting stem cell proliferation comprising contacting hematopoietic cells with a compound capable of activating the Ginhibitory subclass of GTP binding proteins.

55. A method of stimulating or inhibiting stem cell proliferation comprising contacting hematopoietic cells with a compound capable of binding to an opiate-like receptor not including the classical mu, kappa or delta opiate receptors or ORL1, wherein

said receptor (a) has stem cell stimulating and/or inhibiting properties and (b) has said stem cell stimulating and/or inhibiting ability antagonizable by naloxone.

56. A method as in claim 55 wherein said opiate-like receptor has the ability to bind the peptide Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val with a dissociation constant (K_d) less than or equal to 1 micromolar.

57. A method as in claim 55 wherein the dissociation constant is less than or equal to 10 nanomolar.

58. A method of identifying a receptor for INPROL comprising contacting a material which contains said receptor with INPROL in a receptor-binding assay.

59. A method as in method 58 wherein said INPROL is selected from the group
the alpha chain of hemoglobin,the beta chain of hemoglobin,the gamma chain of hemoglobin,
the delta chain of hemoglobin, the epsilon chain of hemoglobin, the zeta chain of hemoglobin,
a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain,
a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain,
Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
biotin-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
(iodo)Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
Phe-Pro-His-(iodo)Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
(iodo)Phe-Pro-His-(iodo)Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,

Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys, and
Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala.

60. A method of identifying a receptor for INPROL comprising contacting a material which contains said receptor with INPROL in an adenylate cyclase assay.

61. A method as in method 60 wherein said INPROL is selected from the group
the alpha chain of hemoglobin,the beta chain of hemoglobin,the gamma chain of hemoglobin, the delta chain of hemoglobin, the epsilon chain of hemoglobin, the zeta chain of hemoglobin
a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain,
a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain,
Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
biotin-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
(iodo)Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
Phe-Pro-His-(iodo)Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
(iodo)Phe-Pro-His-(iodo)Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,
Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys, and
Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala.

62. A method of treating cancer in a mammal suffering therefrom comprising the steps of:

a) administering radiotherapy and/or chemotherapy, and

b) administering a stem cell proliferation stimulatory amount of INPROL and/or an opiate compound.

63. A method as in claim 62 wherein steps a and b are repeated one or more times.

64. A method as in claim 62 wherein step a is conducted before step b.

65. A method as in claim 62 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin..

66. A method of stimulating stem cell division in a mammal exposed to an agent which damages or destroys stem cells comprising administering a stem cell proliferation stimulating amount of INPROL and/or an opiate compound.

67. A method as in claim 66 wherein said agent is an antiviral agent or an anti-neoplastic agent.

68. A method as in claim 66 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

69. A method of maintaining mammalian hematopoietic stem cells *ex vivo* comprising contacting hematopoietic cells with a stem cell proliferation stimulating amount of INPROL and/or an opiate compound.

70. A method as in claim 69 wherein said hematopoietic cells are selected from the group consisting of bone marrow cells, peripheral blood cells, mobilized peripheral blood cells, fetal liver and umbilical cord blood cells.

71. A method as in claim 69 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

72. A method of treating a myeloproliferative disease, hematopoieitic or epithelial stem cell hypoproliferation in a mammal suffering therefrom comprising administering a stimulatory amount of INPROL and/or an opiate compound.

73. A method as in claim 72 wherein said myeloproliferative disease is a myelodysplastic syndrome or aplastic anemia.

74. A method as in claim 72 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

75. A method for treating or preventing stem cell exhaustion comprising administering a stem cell proliferation inhibitory amount of INPROL and/or an opiate compound.

76. A method as in claim 75 wherein said stem cell exhaustion is due to an acquired immune deficiency syndrome.

77. A method as in claim 75 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

78. A method for differentially protecting normal stem cells in a mammal from chemotherapy or radiation comprising administering a stem cell protecting amount of an opiate compound.

79. A method as in claim 78 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

80. A method of conducting gene therapy in a mammal comprising:

a) removing hematopoietic cells from said mammal,

b) treating said hematopoietic cells *ex vivo* with a stem cell stimulatory amount of INPROL and/or an opiate compound,

c) transfecting or infecting said hematopoietic cells with a predetermined gene,

d) contacting said transfected hematopoietic cells *ex vivo* with a stem cell inhibitory amount of INPROL and/or an opiate compound,

e) transplanting into said mammal the hematopoietic cells of step d

f) optionally treating said mammal *in vivo* with a stem cell inhibitory or stimulatory quantity INPROL and/or an opiate compound.

81. A method as in claim 80 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

82. A method for conducting *ex vivo* stem cell expansion comprising contacting hematopoietic cells with a stem cell stimulatory amount of INPROL and/or an opiate compound.

83. A method as in claim 80 wherein said hematopoietic cells are cells selected from the group consisting of bone marrow cells, peripheral blood cells, mobilized peripheral blood cells, fetal liver and umbilical cord blood cells.

84. A method as in claim 80 wherein said opiate compound is selected from the group of morphine, etorphine, codeine, heroin, hydromorphone, oxymorphone, levorphanol, levallorphan, codeine, hydrocodone, oxycodone, nalorphine, naloxone, naltrexone, buprenorphine, butanorphanol, nalbuphine, meperidine, alphaprodine, diphenoxylate, fentanyl, DAMGO, DALDA and nociceptin.

85. A pharmaceutical composition comprising (a) an opiate compound and (b) at least one inhibitory compound selected from the group consisting of MIP-1α, TGFβ, TNFα, INFα, INFβ, INFγ, the pentapeptide pyroGlu-Glu-Asp-Cys-Lys, the tetrapeptide N-Acetyl-Ser-Asp-Lys-Pro, and the tripeptide glutathione (Gly-Cys-γGlu).

86. A pharmaceutical composition comprising (a) an opiate compound and (b) at least one stimulatory compound selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-9, IL-11, IL-13, IL-14, IL-15, G-CSF, GM-CSF, M-CSF, erythropoietin, thrombopoietin, stem cell factor, and flk2/flt3 ligand.

87. A method of treating pain in a mammal comprising administering to said mammal an analgesia-inducing amount of INPROL.

88. A method as in method 87 wherein said INPROL is selected from the group the alpha chain of hemoglobin,the beta chain of hemoglobin,the gamma chain of hemoglobin, the delta chain of hemoglobin, the epsilon chain of hemoglobin, the zeta chain of hemoglobin,

a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain,

a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain,

Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,

Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys, and

Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala.

87. A method of treating immune deficiency in a mammal comprising administering to said mammal an immunostimulatory amount of INPROL.

88. A method as in method 87 wherein said INPROL is selected from the group the alpha chain of hemoglobin,the beta chain of hemoglobin,the gamma chain of hemoglobin, the delta chain of hemoglobin, the epsilon chain of hemoglobin, the zeta chain of hemoglobin,

a polypeptide having the sequence of amino acids 1-97 of the human alpha hemoglobin chain,

a polypeptide having the sequence of amino acids 1-94 of the human alpha hemoglobin chain,

Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val,

Cys-Phe-Pro-His-Phe-Asp-Leu-Ser-His-Gly-Ser-Ala-Gln-Val-Cys, and

Asp-Ala-Leu-Thr-Asn-Ala-Val-Ala-His-Val-Asp-Asp-Met-Pro-Asn-Ala-Leu-Ser-Ala.

ABSTRACT OF THE DISCLOSURE

Disclosed and claimed are methods for the isolation and use of stem cell modulating factors for regulating stem cell cycle and for accelerating the post-chemotherapy peripheral blood cell recovery. Also disclosed and claimed are the inhibitors and stimulators of stem cell proliferation.

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

INHIBITOR AND STIMULATOR OF STEM CELL PROLIFERATION AND USES THEREOF

the specification of which (**check** applicable **box(s)**):

[x] is attached hereto

[ ] was filed on _____ as U.S. Application Serial No. _____ **(Atty Dkt. No.)**.

[ ] was filed as PCT international application No. _____ on _____

a n d (if applicable to U.S. or PCT application) was amended on _____.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed or, if no priority is claimed, before the filing date of this application:

Prior Foreign Application(s):

Application Number	**Country**	**Day/Month/Year Filed**

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

Application Number	**Day/Month/Year Filed**

I hereby claim the benefit under 35 U.S.C. 120/365 of all prior United States and PCT international applications listed above or below and, insofar as the subject matter of each of the claims of this application is not disclosed in such prior applications in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose material information as defined in 37 C.F.R. 1.56 which occurred between the filing date of the prior applications and the national or PCT international filing date of this application:

Prior U.S./PCT Application(s): Application Serial No.	**Day/Month/Year Filed**	**Status: patented, pending, abandoned**
08/627,173	**3 April 1996**	**pending**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. And I hereby appoint **NIXON & VANDERHYE P.C., 1100 North Glebe Rd., 8th Floor, Arlington, VA 22201-4714, telephone number (703) 816-4000 (to whom all communications are to be directed)**, and the following attorneys thereof (of the same address) individually and collectively my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent: Arthur R. Crawford, 25327; Larry S. Nixon, 25640; Robert A. Vanderhye, 27076; James T. Hosmer, 30184; Robert W. Faris, 31352, Richard G. Besha, 22770; Mark E. Nusbaum, 32348; Michael J. Keenan, 32106; Bryan H. Davidson, 30251; Stanley C. Spooner, 27393; Leonard C. Mitchard, 29009; Duane M. Byers, 33363; Paul J. Henon, 33626; Jeffry H. Nelson, 30481; John R. Lastova, 33149; H. Warren Burnam, Jr., 29366; Thomas E. Byrne, 32205; Mary J. Wilson, 32955; J. Scott Davidson, 33489; Alan M. Kagen, 36178; William J. Griffin, 31260; Robert A. Molan, 29834.

1. Inventor's Signature: _____ Date: 4/3/97
   Inventor: **STEPHEN** (first) **D.** MI **WOLPE** (last) **U.S.** (citizenship)
   Residence: (city) **Rockville** (state/country) **Maryland**
   Post Office Address: **10821-200 Hampton Mills Terrace, Rockville, MD**
   (Zip Code) **20852**

2. Inventor's Signature: _____ Date: 4. 3. 97
   Inventor: **IRENA** (first) MI **TSYRLOVA** (last) **RUSSIAN** (citizenship)
   Residence: (city) **Gaithersburg** (state/country) **Maryland**
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   (Zip Code) **20879**

3. Inventor's Signature: _____ Date: _____
   Inventor: (first) MI (last) (citizenship)
   Residence: (city) _____ (state/country) _____
   Post Office Address: _____
   (Zip Code) _____

FOR ADDITIONAL INVENTORS, check box [ ] **and attach sheet with same information and signature and date for each.**

OMB No. 0651-0011 (12/31/86)

Applicant or Patentee: Stephen D. WOLPE and Irena Tsyrlova Attorney's

Serial or Patent No.: Dkt. No.: 1331-222

Filed or Issued: April 3, 1996

For: INHIBITOR AND STIMULATOR OF STEM CELL PROLIFERATION AND USES THEREOF

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 1.9(f) and 1.27 (c)) - SMALL BUSINESS CONCERN

I hereby declare that I am

[ ] the owner of the small business concern identified below:

[X] an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN Pro-Neuron, Inc.

ADDRESS OF CONCERN 1530 East Jefferson Street ,Rockville,MD 20852

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9 (d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled:

INHIBITOR AND STIMULATOR OF STEM CELL PROLIFERATION AND USES THEREOF

by inventor(s) Stephen D. WOLPE, and Irena TSYRLOVA described in

[X] the specification filed herewith.

[ ] application serial no. _____, filed _____.

[ ] patent no. _____, issued _____.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9 (d), or a nonprofit organization under 37 CFR 1.9 (e). *NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME _____

ADDRESS _____

[ ] Individual [ ] Small Business Concern [ ] Nonprofit Organization

NAME _____

ADDRESS _____

[ ] Individual [ ] Small Business Concern [ ] Nonprofit Organization

I aoknowledge the duty to file, in this application of patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Michael K. Bamat

TITLE OF PERSON OTHER THAN OWNER Vice President

ADDRESS OF PERSON SIGNING 1530 East Jefferson Street, Rockville, MD 20852

SIGNATURE Michael K Bamat DATE April 3, 1997

209819

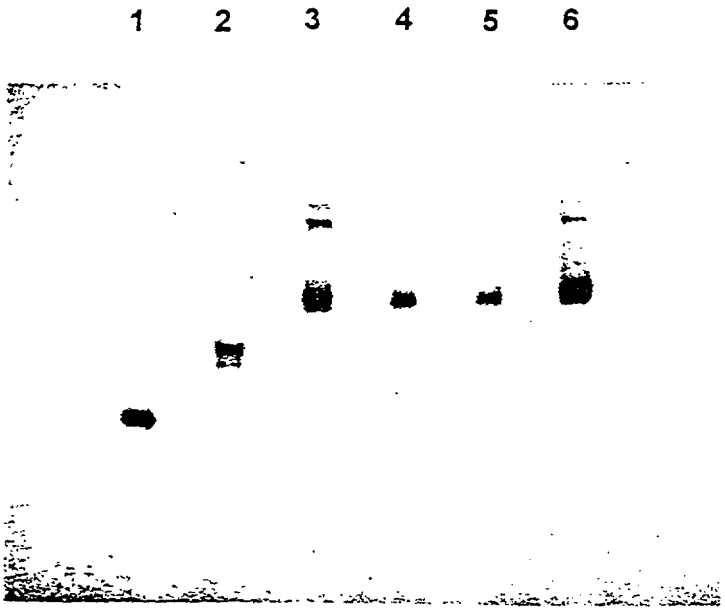


FIG. 1

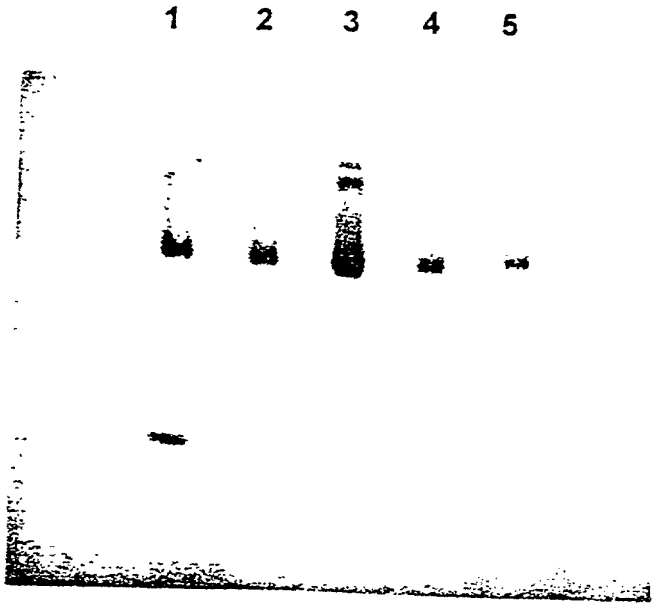


FIG. 2

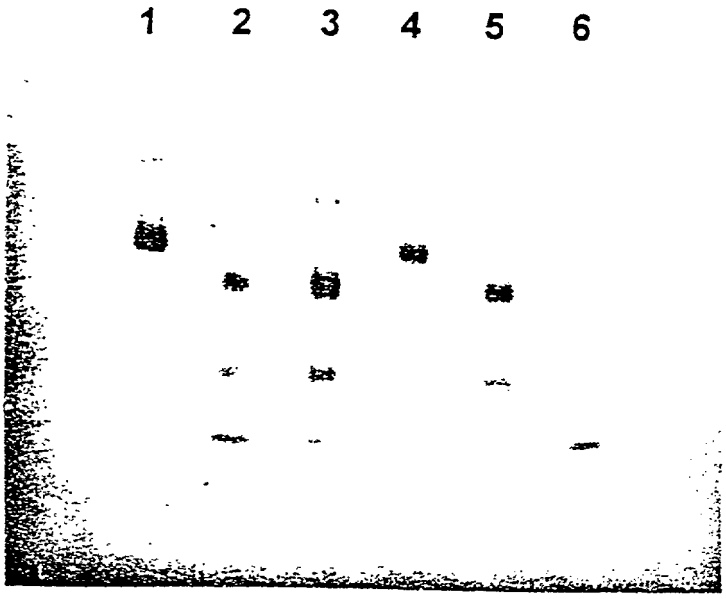


FIG. 3

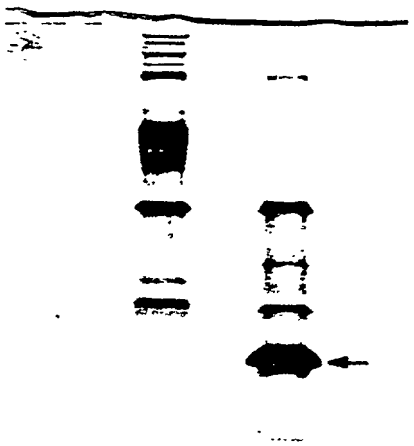


FIG. 4

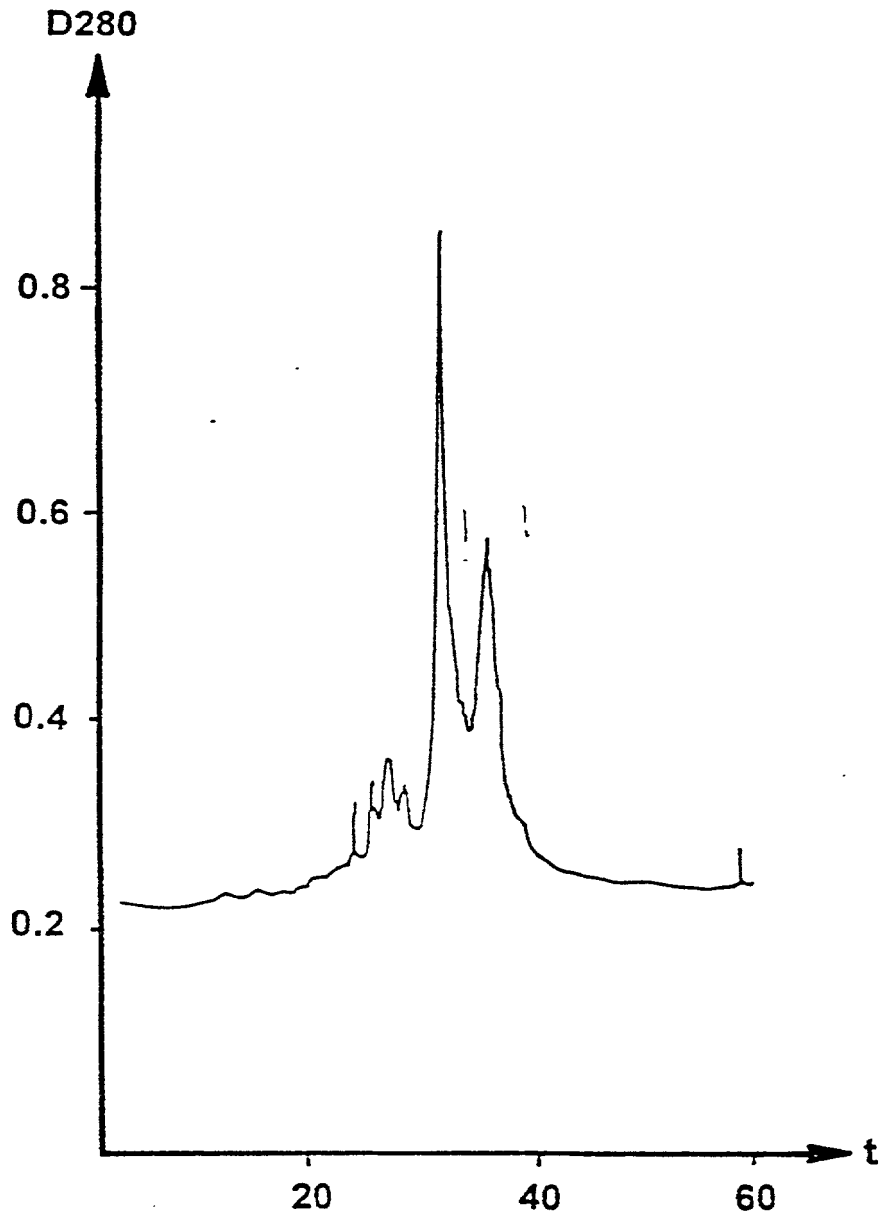


FIG. 5

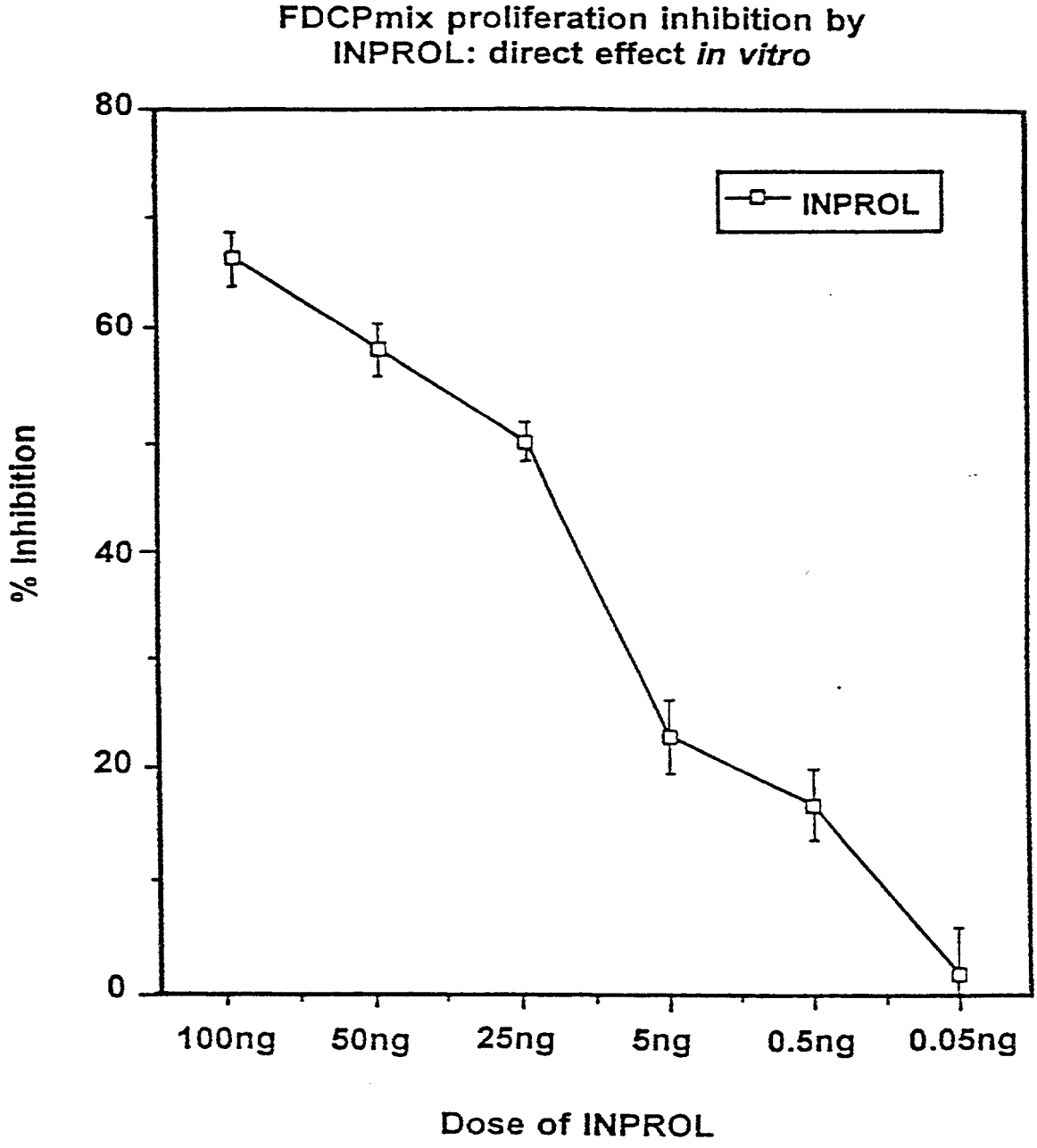

FDCPmix proliferation inhibition by INPROL: direct effect *in vitro*
INPROL
% Inhibition
80
60
40
20
0
100ng
50ng
25ng
5ng
0.5ng
0.05ng
Dose of INPROL

FIG. 6

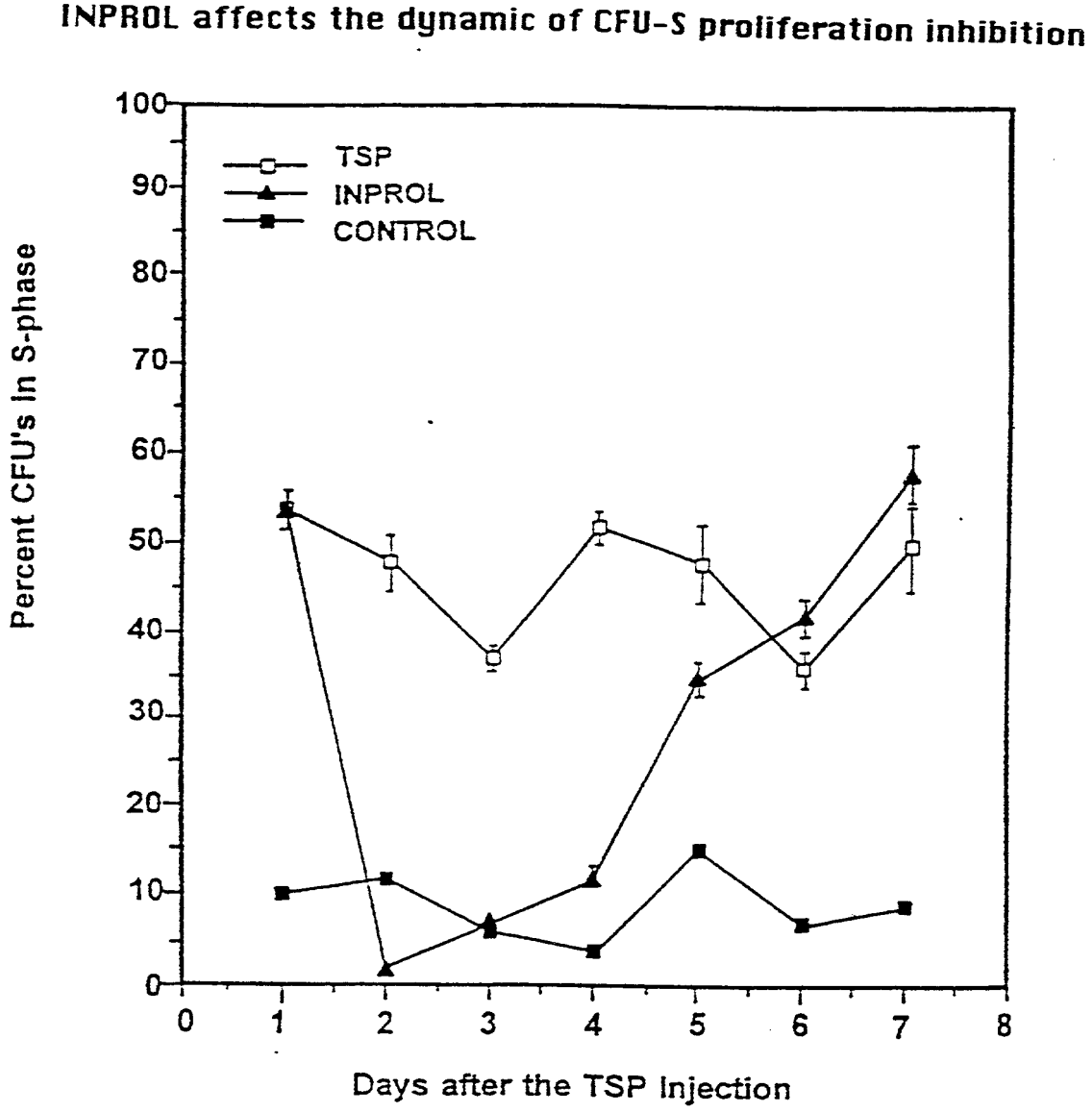
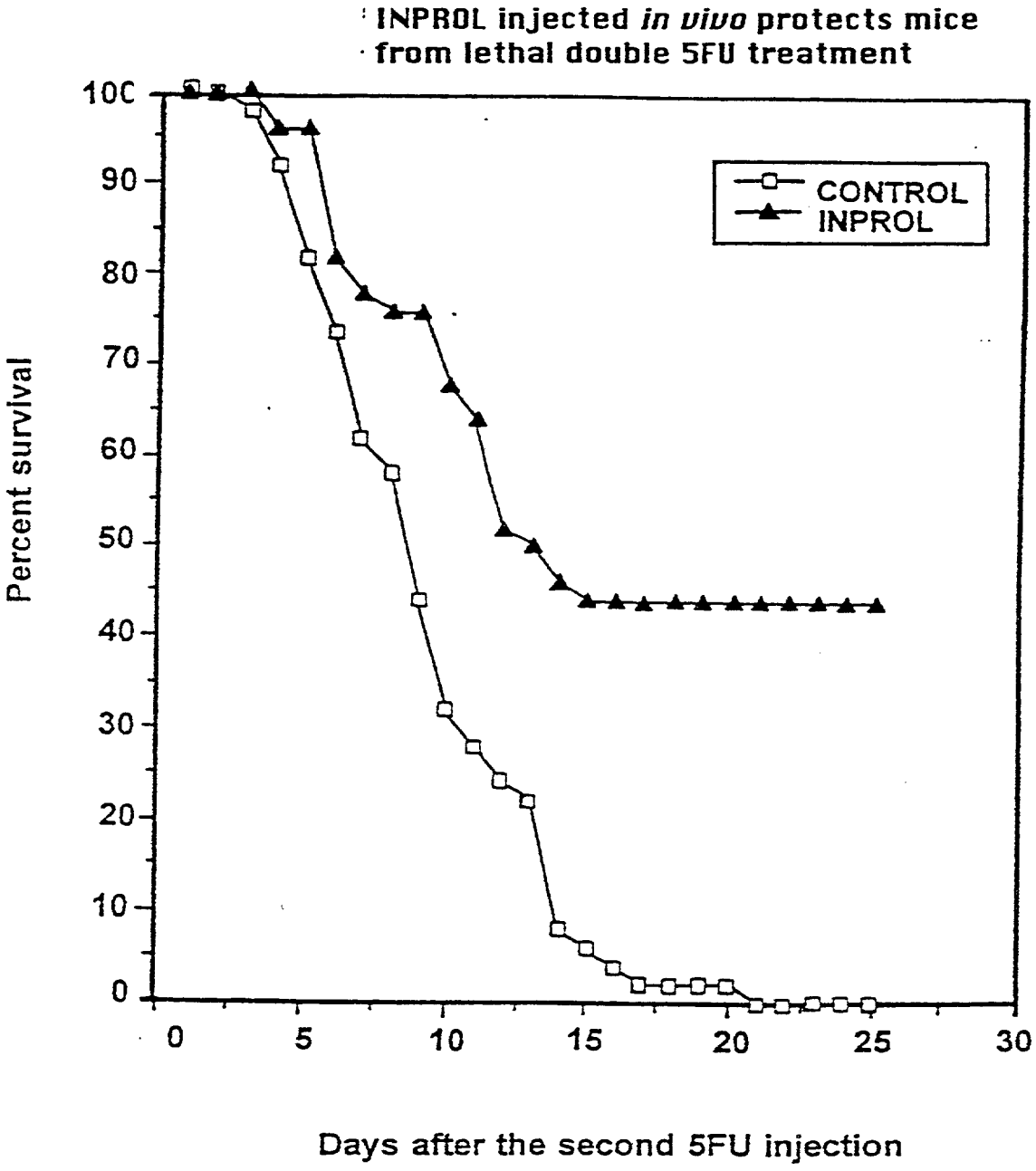

INPROL affects the dynamic of CFU-S proliferation inhibition
TSP
INPROL
CONTROL
Percent CFU's In S-phase
Days after the TSP Injection
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8

FIG. 7

FIG. 8


INPROL injected *in vivo* protects mice from lethal double 5FU treatment
CONTROL
INPROL
Percent survival
Days after the second 5FU injection
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30

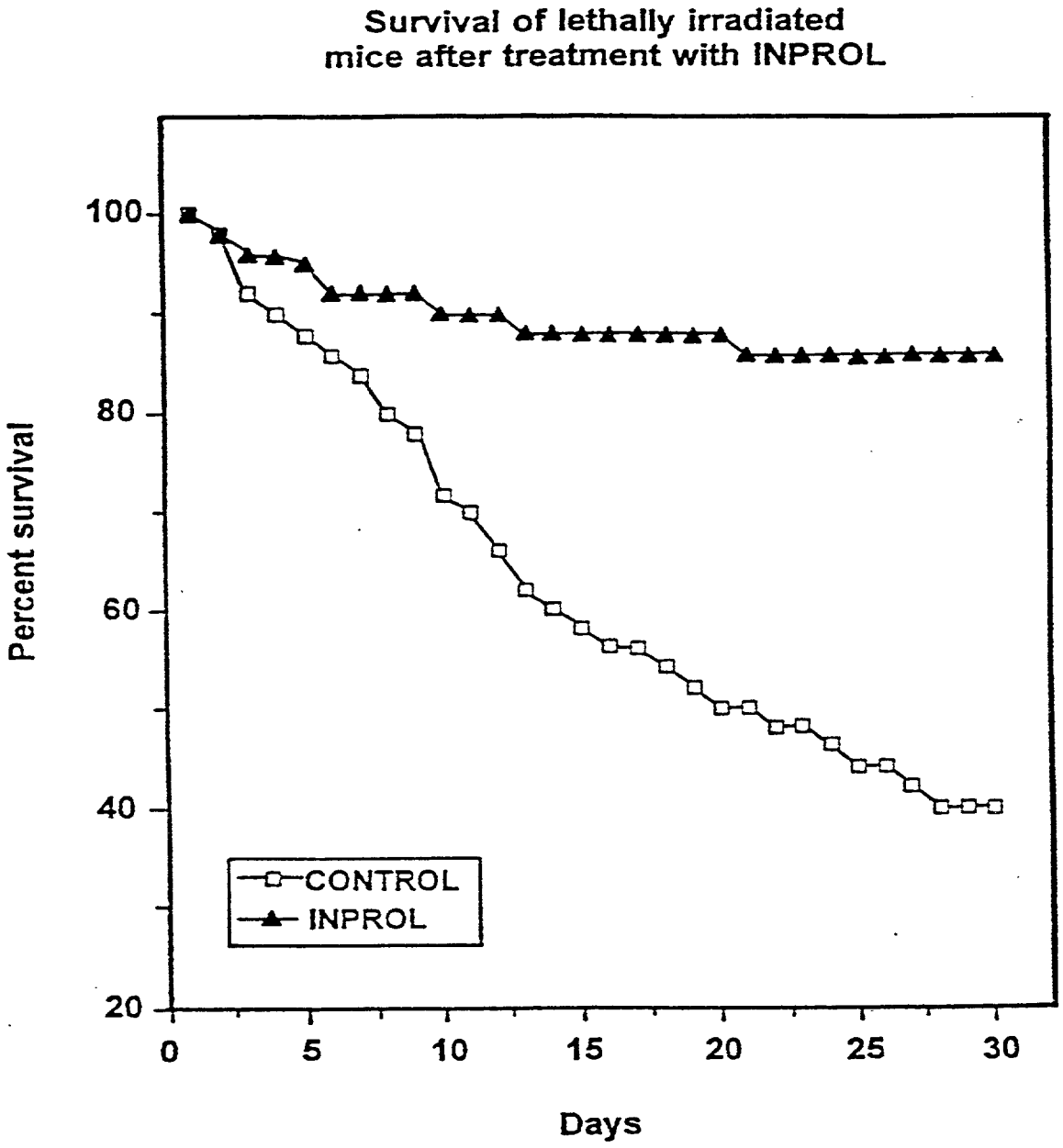

Survival of lethally irradiated
mice after treatment with INPROL
Percent survival
100
80
60
40
20
0
5
10
15
20
25
30
Days
CONTROL
INPROL

FIG. 9

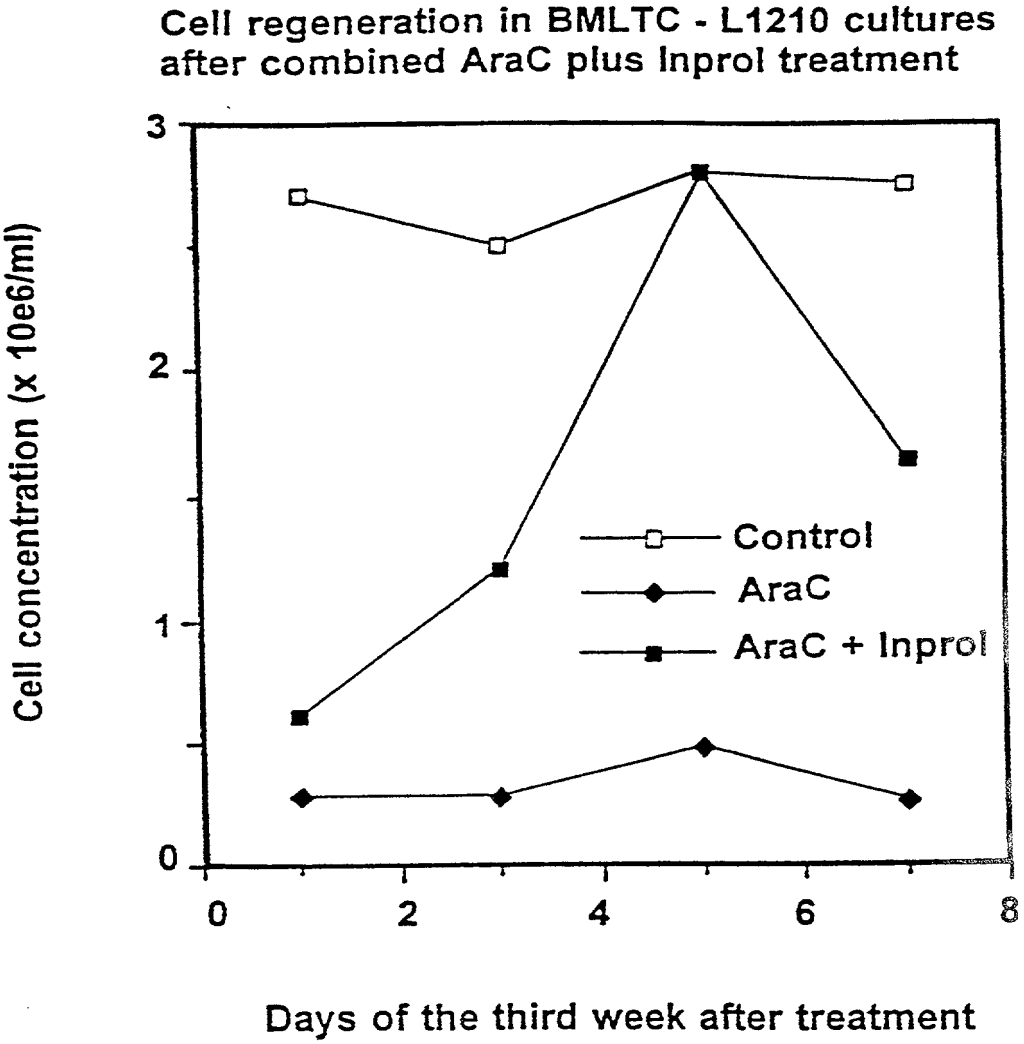

Cell regeneration in BMLTC - L1210 cultures
after combined AraC plus Inprol treatment
Cell concentration (x 10e6/ml)
3
2
1
0
0
2
4
6
8
Control
AraC
AraC + Inprol
Days of the third week after treatment

FIG. 10B

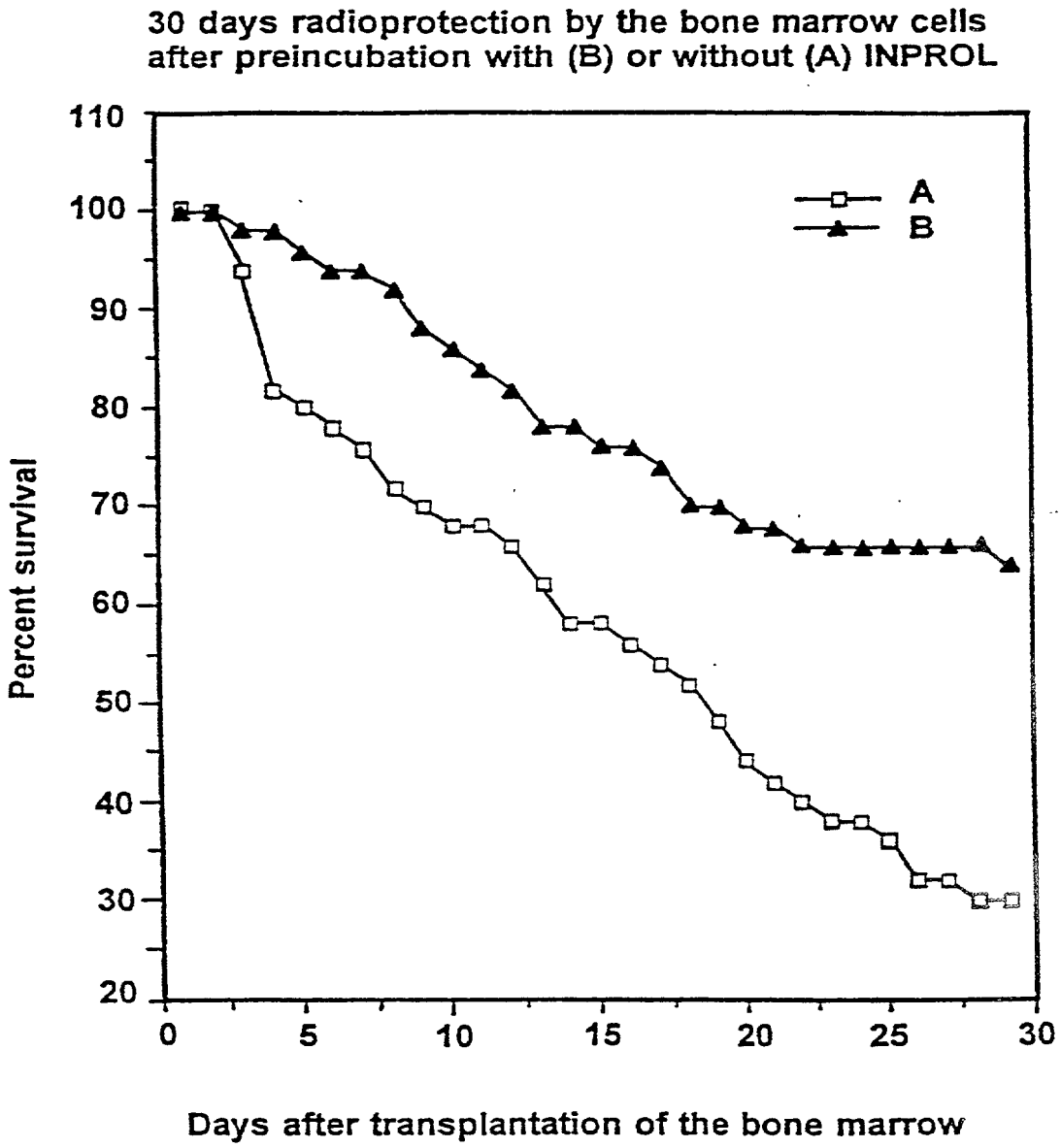

30 days radioprotection by the bone marrow cells after preincubation with (B) or without (A) INPROL
Percent survival
110
100
90
80
70
60
50
40
30
20
0
5
10
15
20
25
30
A
B
Days after transplantation of the bone marrow

FIG. 11

Marrow repopulating ability of BDF1 mice cells after incubation with INPROL

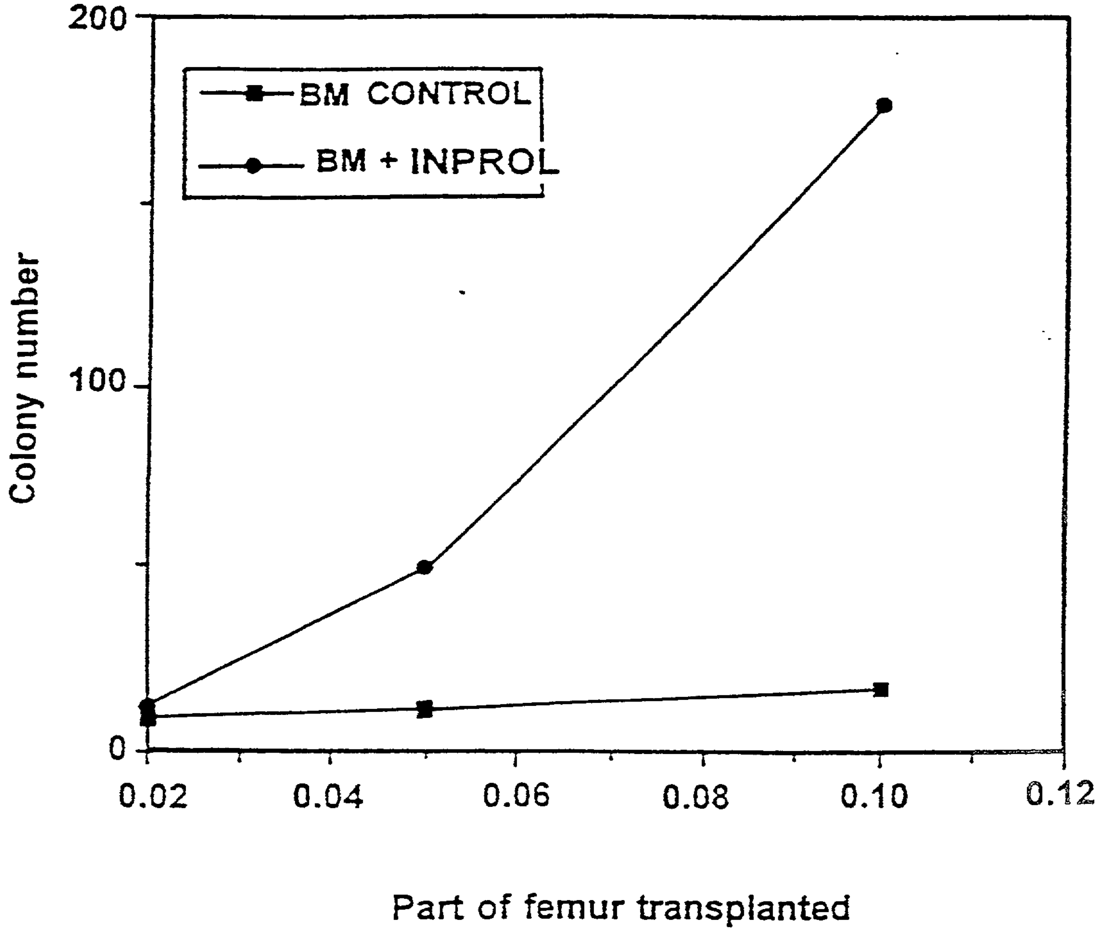


FIG. 12

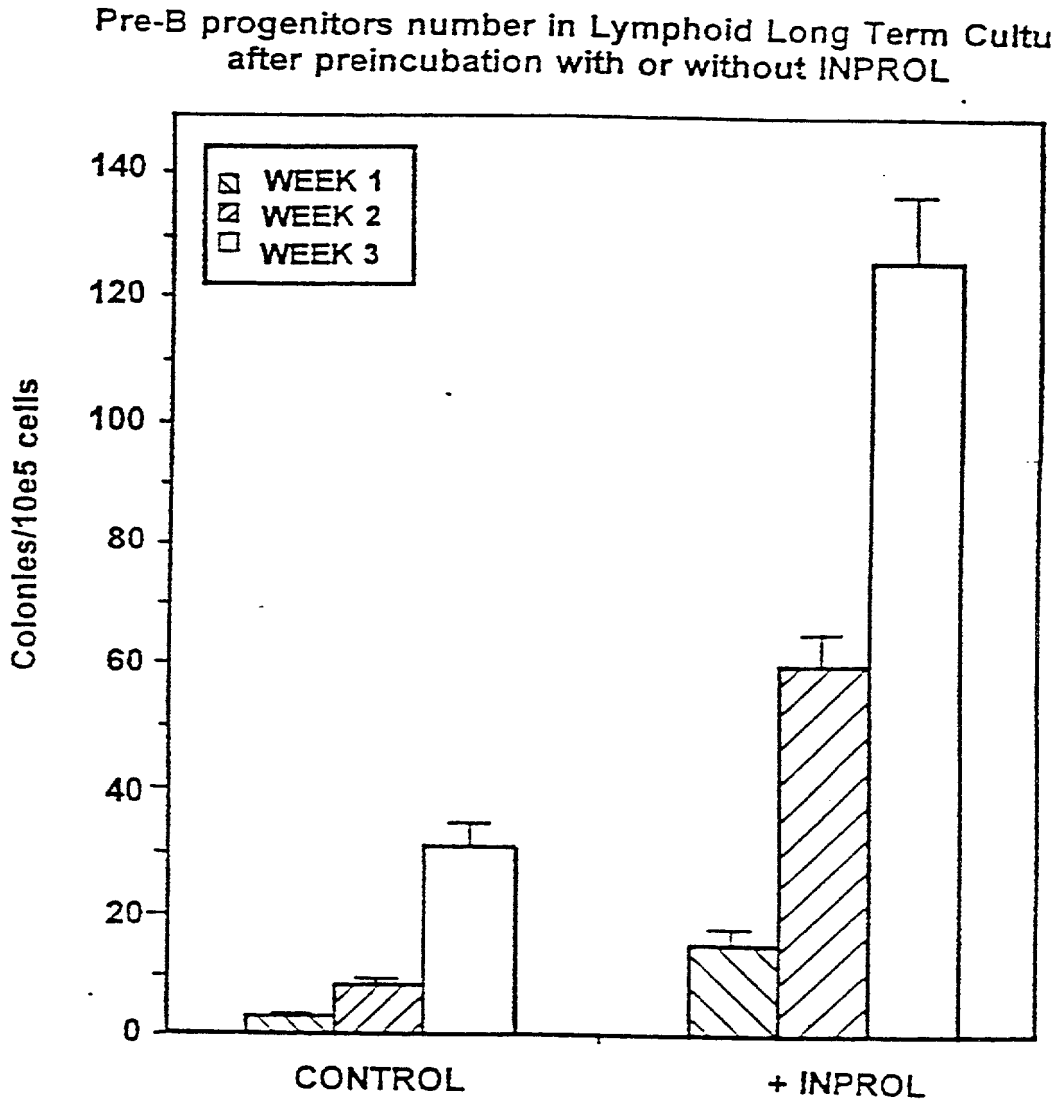

Pre-B progenitors number in Lymphoid Long Term Culture
after preincubation with or without INPROL
WEEK 1
WEEK 2
WEEK 3
Colonies/10e5 cells
140
120
100
80
60
40
20
0
CONTROL
+ INPROL

FIG. 13

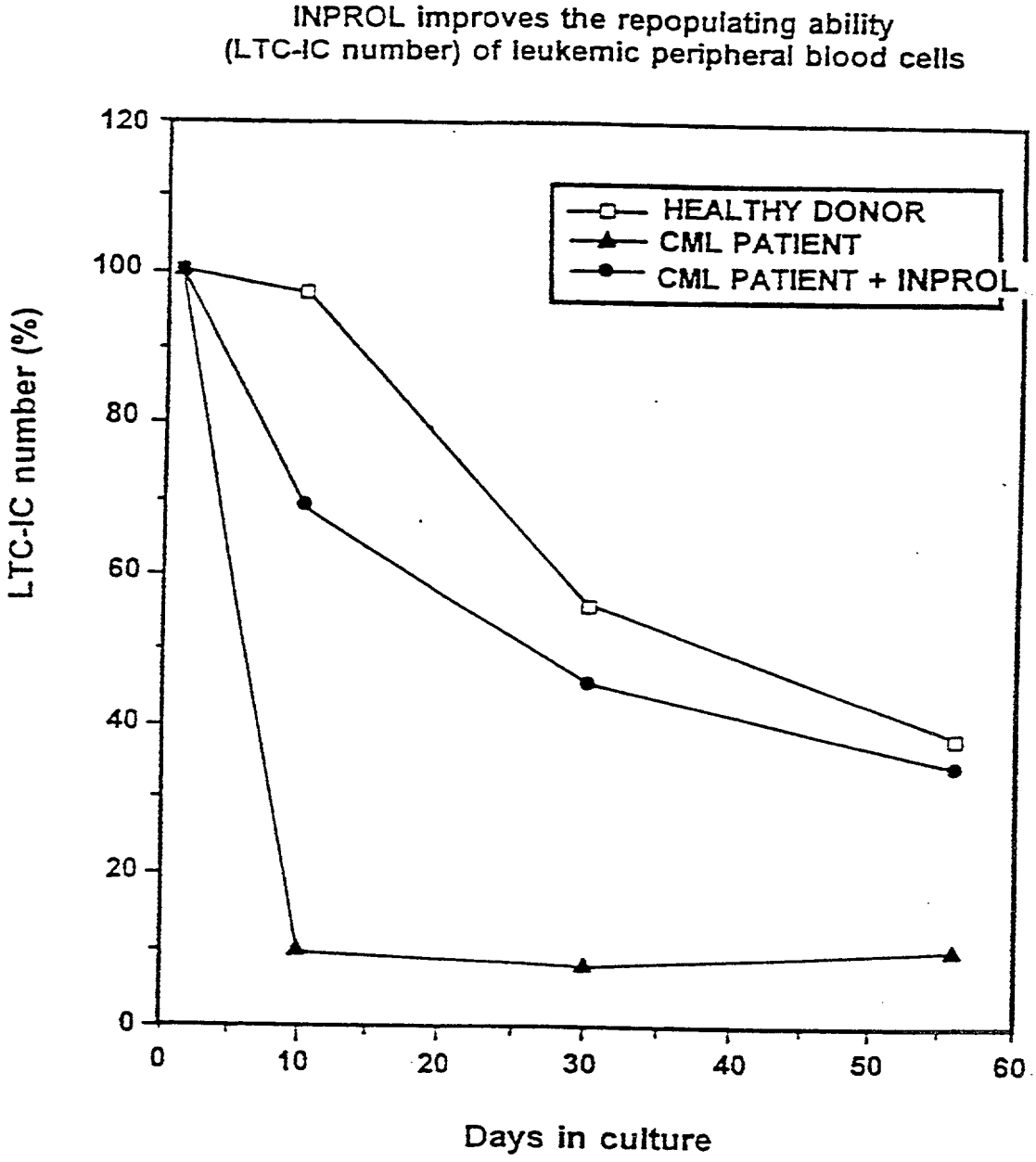
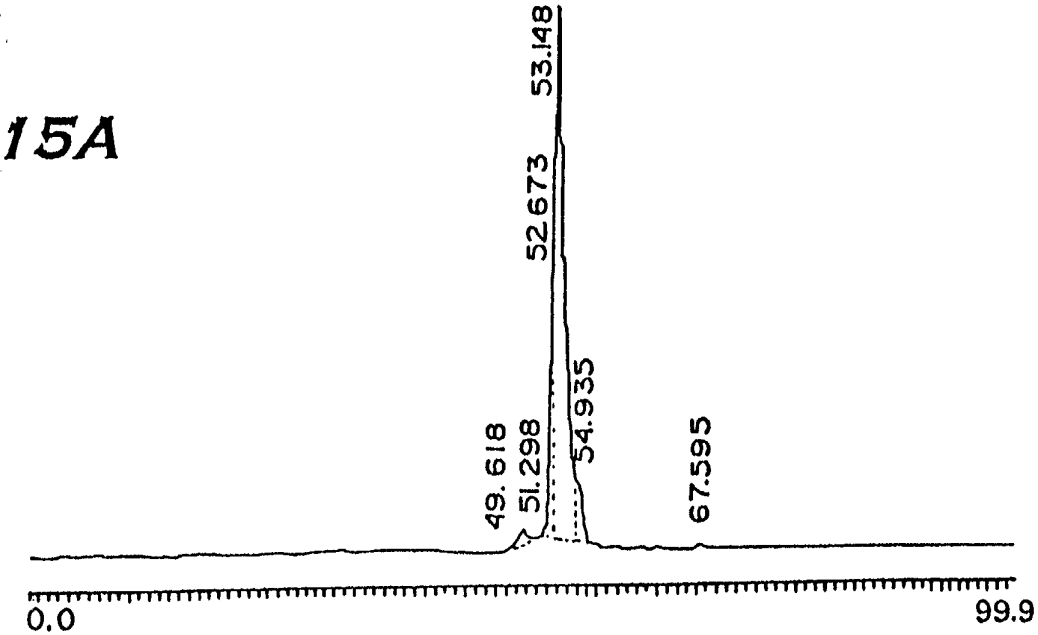

INPROL improves the repopulating ability
(LTC-IC number) of leukemic peripheral blood cells
LTC-IC number (%)
120
100
80
60
40
20
0
0
10
20
30
40
50
60
Days in culture
HEALTHY DONOR
CML PATIENT
CML PATIENT + INPROL

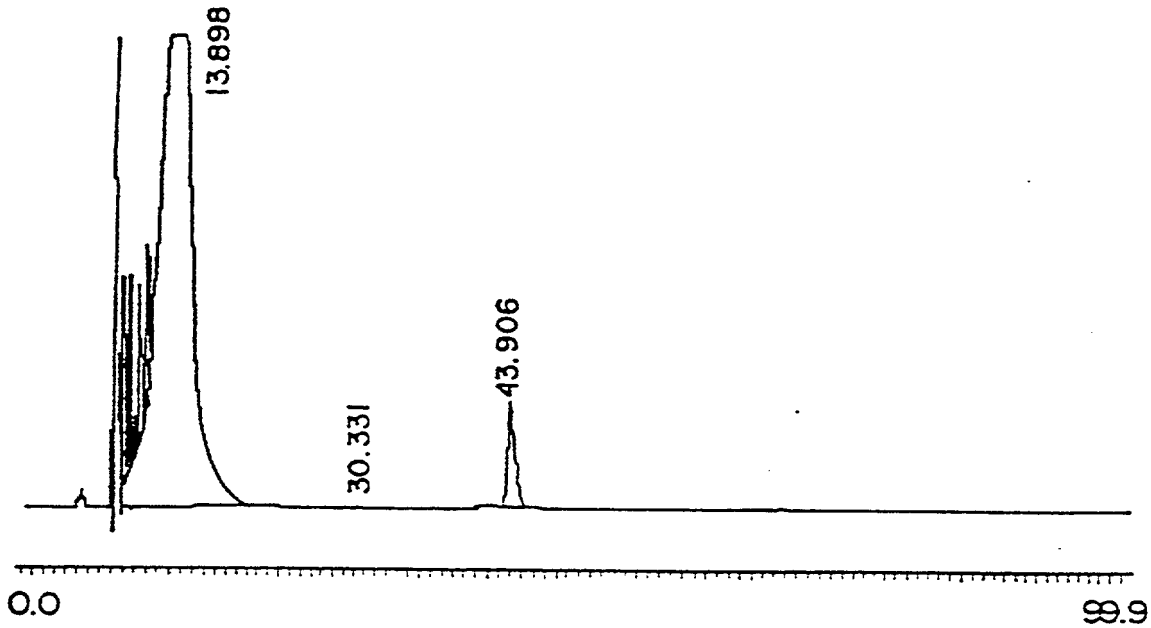
FIG. 14

FIG. 15A



Analysis: Channel A

Peak No.	Time	Type	Height(μY)	Area(μY-sec)	Area%
	3.126	N1	691	7578	0.041
	3.315	N2	1011	5150	0.027
1	49.618	N	8584	349227	1.893
2	51.298	N	1456	20274	0.109
3	52.673	N1	138069	2633395	14.278
4	53.148	N2	271587	14050458	76.181
5	54.935	N3	33016	1332820	7.226
6	67.595	N	3270	44507	0.241
TOTAL AREA				18443409	99.996



Analysis: Channel A

Peak No.	Time	Type	Height(μY)	Area(μY-sec)	Area%
1	4.383	N1	3945	95125	0.119
2	5.080	N2	28639	330889	0.413
3	5.216	N3	49084	531867	0.665
4	7.980	N1	399424	1110511	1.389
5	8.100	Err'	1203320	2882013	3.605
6	8.241	N3	443249	1506159	1.884
7	8.386	N4	481563	2185702	2.734
8	8.533	N5	412886	1826165	2.284
9	8.701	N6	321500	842122	1.053
10	8.745	N7	404661	1610380	2.014
11	8.995	N8	435765	2489721	3.114
12	9.316	N9	517790	4801831	6.007

FIG. 15B

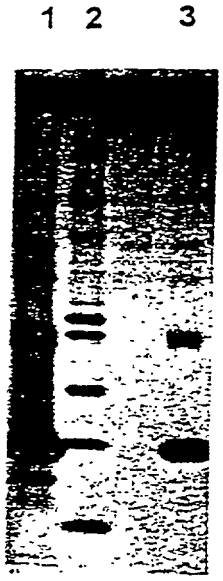


FIG. 15C

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Val	Leu	Ser	Pro	Ala	Asp	Lys	Thr	Asn	Val	Lys	Ala	Ala	Trp	Gly	Lys	Val	Gly	Ala	His
GTG	CTG	TCT	CCT	GCC	GAC	AAG	ACC	AAC	GTC	AAG	GCC	GCC	TGG	GGT	AAG	GTC	GGC	GCG	CAC

21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ala	Gly	Glu	Tyr	Gly	Ala	Glu	Ala	Leu	Glu	Arg	Met	Phe	Leu	Ser	Phe	Pro	Thr	Thr	Lys
GCT	GGC	GAG	TAT	GGT	GCG	GAG	GCC	CTG	GAG	AGg	ATG	TTC	CTG	TCC	TTC	CCC	ACC	ACC	AAG

41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Thr	Tyr	Phe	Pro	His	Phe	Asp	Leu	Ser	His	Gly	Ser	Ala	Gln	Val	Lys	Gly	His	Gly	Lys
ACC	TAC	TTC	CCG	CAC	TTC	GAC	CTG	AGC	CAC	GGC	TCT	GCC	CAG	GTT	AAG	GGC	CAC	GGC	AAG

61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Lys	Val	Ala	Asp	Ala	Leu	Thr	Asn	Ala	Val	Ala	His	Val	Asp	Asp	Met	Pro	Asn	Ala	Leu
AAG	GTG	GCC	GAC	GCG	CTG	ACC	AAC	GCC	GTG	GCG	CAC	GTG	GAC	GAC	ATG	CCC	AAC	GCG	CTG

81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ser	Ala	Leu	Ser	Asp	Leu	His	Ala	His	Lys	Leu	Arg	Val	Asp	Pro	Val	Asn	Phe	Lys	Leu
TCC	GCC	CTG	AGC	GAC	CTG	CAC	GCG	CAC	AAG	CTT	CGG	GTG	GAC	CCG	GTC	AAC	TTC	AAG	CTC

101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Leu	Ser	His	Cys	Leu	Leu	Val	Thr	Leu	Ala	Ala	His	Leu	Pro	Ala	Glu	Phe	Thr	Pro	Ala
CTA	AGC	CAC	TGC	CTG	CTG	GTG	ACC	CTG	GCC	GCG	CAC	CTC	CCC	GCC	GAG	TTC	ACC	CCT	GCG

121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141
Val	His	Ala	Ser	Leu	Asp	Lys	Phe	Leu	Ala	Ser	Val	Ser	Thr	Val	Leu	Thr	Ser	Lys	Tyr	Arg
GTG	CAC	GCC	TCC	CTG	GAC	AAG	TTC	CTG	GCT	TCT	GTG	AGC	ACC	GTG	CTG	ACC	TCC	AAA	TAC	CGT

Fig. 16A

```
 1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18  19  20
Val His Leu Thr Pro Glu Glu Lys Ser Ala Val Thr Ala Leu Trp Gly Lys Val Asn Val
GTG CAC CTG ACT CCT GAG GAG AAG TCT GCC GTT ACT GCC CTG TGG GGC AAG GTG AAC GTG

 21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40
Asp Glu Val Gly Gly Glu Ala Leu Gly Arg Leu Leu Val Val Tyr Pro Trp Thr Gln Arg
GAT GAA GTT GGT GGT GAG GCC CTG GGC AGg CTG CTG GTG GTC TAC CTT TGG ACC CAG AGG

 41  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60
Phe Phe Glu Ser Phe Gly Asp Leu Ser Thr Pro Asp Ala Val Met Gly Asn Pro Lys Val
TTC TTT GAG TCC TTT GGG GAT CTG TCC ACT CCT GAT GCT GTt ATG GGC AAC CCT AAG GTG

 61  62  63  64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
Lys Ala His Gly Lys Lys Val Leu Gly Ala Phe Ser Asp Gly Leu Ala His Leu Asp Asn
AAG GCT CAT GGC AAG AAA GTG CTC GGT GCC TTT AGT GAT GGC CTG GCT CAC CTG GAC AAC

 81  82  83  84  85  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100
Leu Lys Gly Thr Phe Ala Thr Leu Ser Glu Leu His Cys Asp Lys Leu His Val Asp Pro
CTC AAG GGC ACC TTT GCC ACA CTG AGT GAG CTG CAC TGT GAC AAG CTG CAC GTG GAT CCT

101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
Glu Asn Phe Arg Leu Leu Gly Asn Val Leu Val Cys Val Leu Ala His His Phe Gly Lys
GAG AAC TTC AGG CTG CTG GGC AAC GTG CTG GTC TGT GTG CTG GCC CAT CAC TTT GGC AAA

121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140
Glu Phe Thr Pro Pro Val Gln Ala Ala Tyr Gln Lys Val Val Ala Gly Val Ala Asn Ala
GAA TTC ACC CCA CCA GTG CAG GCT GCC TAT CAG AAA GTG GTG GCT GGT GTG GCT AAT GCC

141 142 143 144 145 146
Leu Ala His Lys Tyr His
CTG GCC CAC AAG TAT CAC
```

Fig. 16B

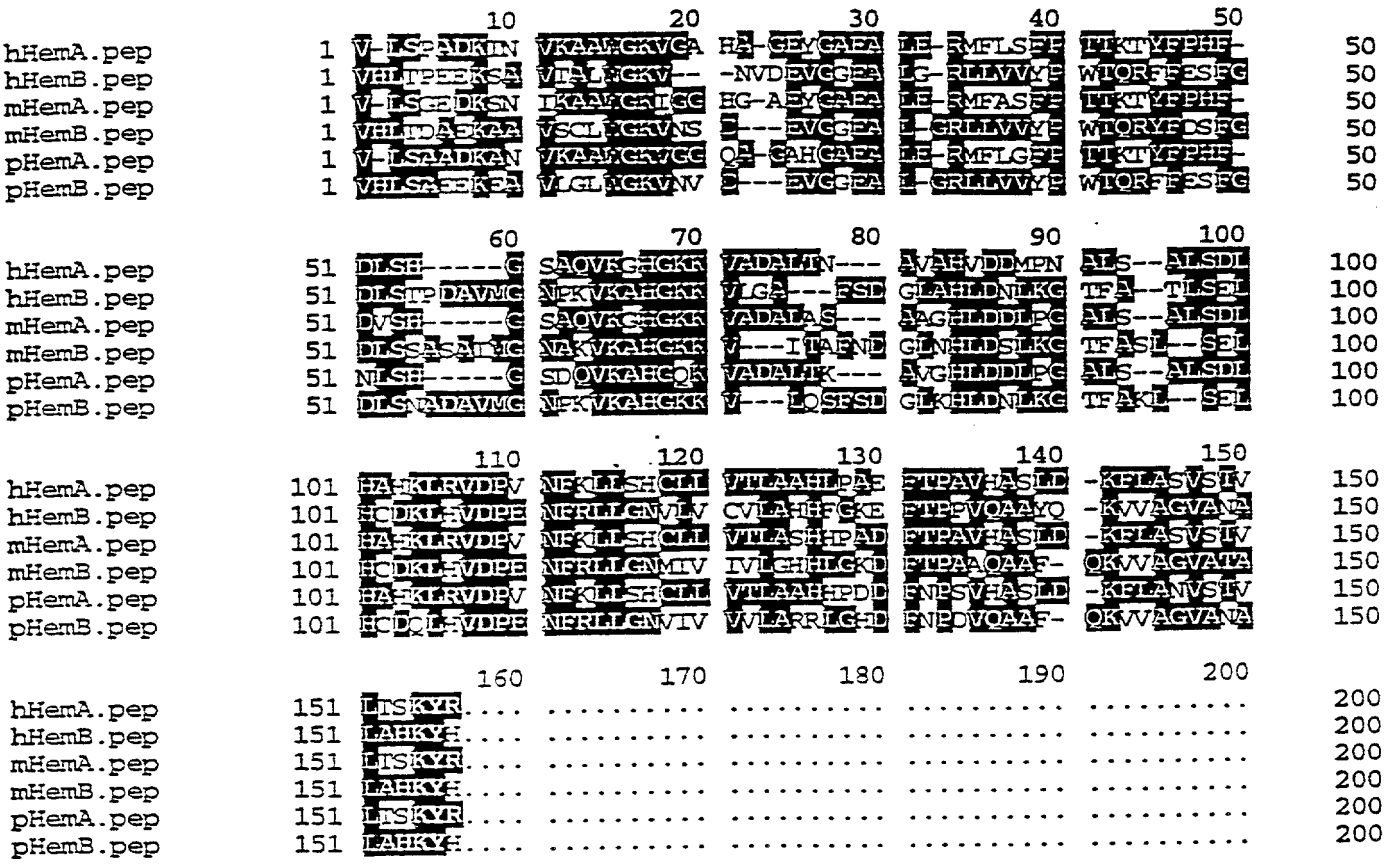
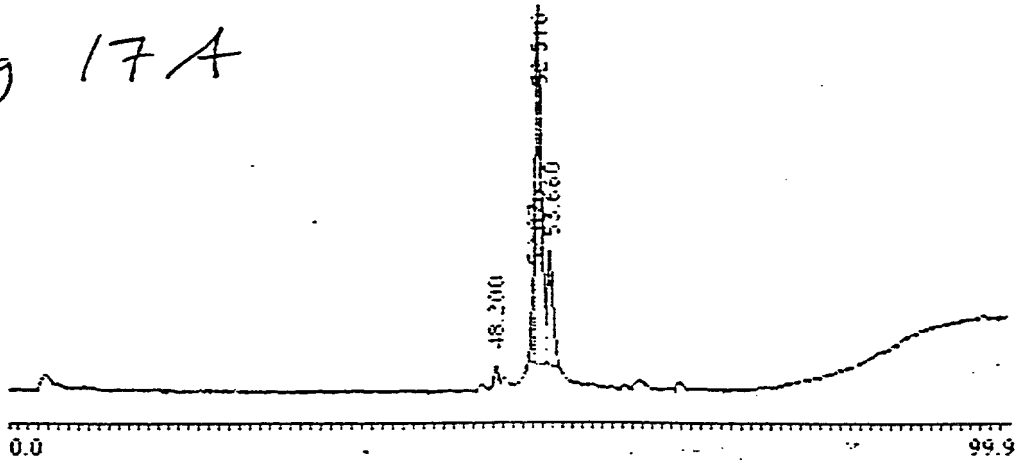

10 20 30 40 50
hHemA.pep 1 V-LSPADKTN VKAAWGKVGA H--GEYGAEA LE-RMFLSFP TTKTYFPHF- 50
hHemB.pep 1 VHLTPEEKSA VTALWGKV-- -NVDEVGGEA LG-RLLVVYP WTQRFFESFG 50
mHemA.pep 1 V-LSGEDKSN IKAAWGKIGG HG-AEYGAEA LE-RMFASFP TTKTYFPHF- 50
mHemB.pep 1 VHLTDAEKAA VSCLWGKVNS D---EVGGEA L-GRLLVVYP WTQRYFDSFG 50
pHemA.pep 1 V-LSAADKAN VKAAWGKVGG QA-GAHGAEA LE-RMFLGFP TTKTYFPHF- 50
pHemB.pep 1 VHLSAEEKSA VLGLWGKVNV D---EVGGEA L-GRLLVVYP WTQRFFESFG 50
60 70 80 90 100
hHemA.pep 51 DLSH-----G SAQVKGHGKK VADALTN--- AVAHVDDMPN ALS--ALSDL 100
hHemB.pep 51 DLSTPDAVMG NPKVKAHGKK VLGA---FSD GLAHLDNLKG TFA--TLSEL 100
mHemA.pep 51 DVSH-----G SAQVKGHGKK VADALAS--- AAGHLDDLPG ALS--ALSDL 100
mHemB.pep 51 DLSSASAIMG NAKVKAHGKK V---ITAFND GLNHLDSLKG TFASL--SEL 100
pHemA.pep 51 NLSH-----G SDQVKAHGQK VADALHK--- AVGHLDDLPG ALS--ALSDL 100
pHemB.pep 51 DLSNADAVMG NPKVKAHGKK V---LQSFSD GLKHLDNLKG TFAKL--SEL 100
110 120 130 140 150
hHemA.pep 101 HAHKLRVDPV NFKLLSHCLL VTLAAHLPAE FTPAVHASLD -KFLASVSTV 150
hHemB.pep 101 HCDKLRVDPE NFRLLGNVLV CVLAHHFGKE FTPPVQAAYQ -KVVAGVANA 150
mHemA.pep 101 HAHKLRVDPV NFKLLSHCLL VTLASHHPAD FTPAVHASLD -KFLASVSIV 150
mHemB.pep 101 HCDKLRVDPE NFRLLGNMIV IVLGHHLGKD FTPAAQAAF- QKVVAGVATA 150
pHemA.pep 101 HAHKLRVDPV NFKLLSHCLL VTLAAHHPDD FNPSVHASLD -KFLANVSTV 150
pHemB.pep 101 HCDQLRVDPE NFRLLGNVIV VVLARRLGHD FNPDVQAAF- QKVVAGVANA 150
160 170 180 190 200
hHemA.pep 151 LTSKYR.... 200
hHemB.pep 151 LAHKYH.... 200
mHemA.pep 151 LTSKYR.... 200
mHemB.pep 151 LAHKYH.... 200
pHemA.pep 151 LTSKYR.... 200
pHemB.pep 151 LAHKYH.... 200

Fig. 16C

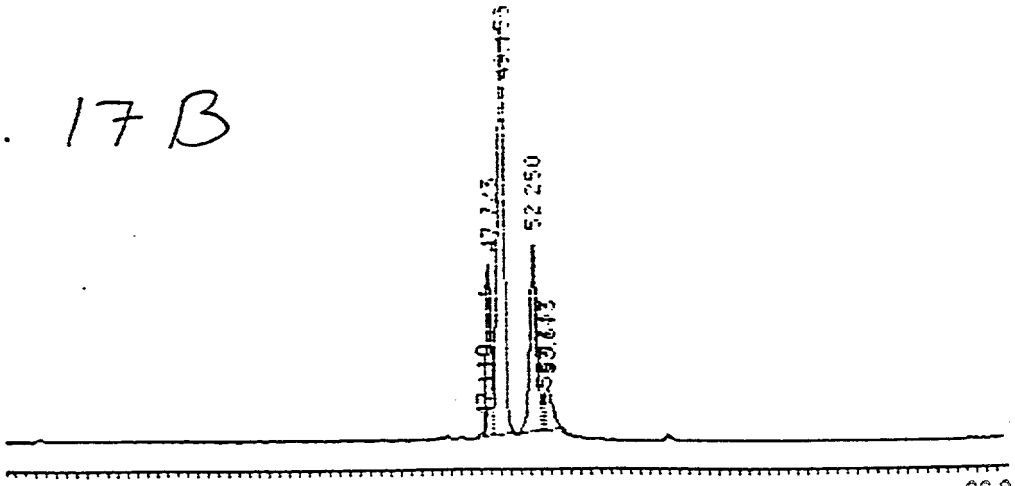
Fig 17A



Analysis. Channel A

Peak No	Time	Type	Height(μV)	Area(μV-sec)	Area%
1	48.200	N	1677	20438	1.515
2	52.076	N1	7[illegible]	116393	8.631
3	52.510	N2	32010	881490	65.369
4	53.660	N3	10066	330153	24.483
Total Area				1348474	99.998

Fig. 17B



Analysis: Channel A

Peak No.	Time	Type	Height(μV)	Area(μV-sec)	Area%
1	47.110	N1	1727	24840	0.204
2	47.723	N2	75067	1738939	14.321
3	49.153	N3	188795	6206410	51.114
4	52.250	N1	81476	3046748	25.092
5	53.113	N2	13195	202166	1.664
6	53.613	N3	19211	914954	7.535
	65.753	N	818	8066	0.066
Total Area				12142123	99.996

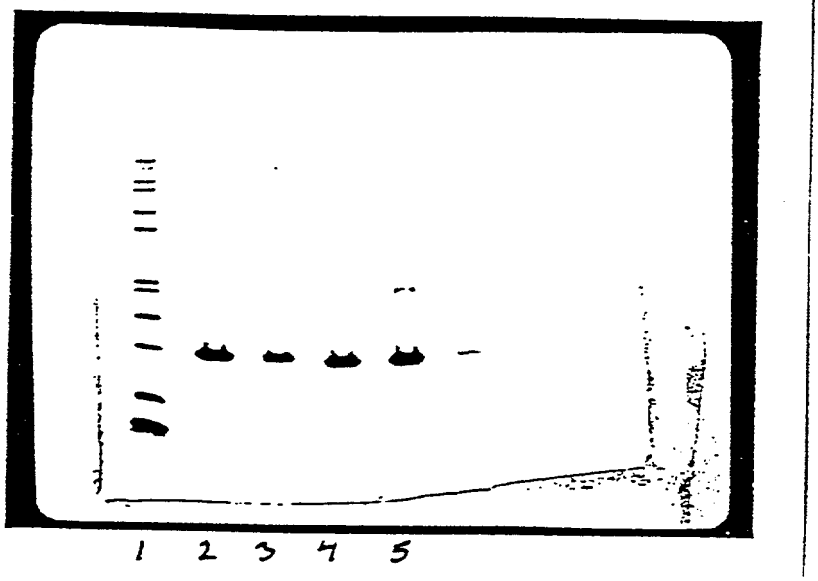


Fig. 18

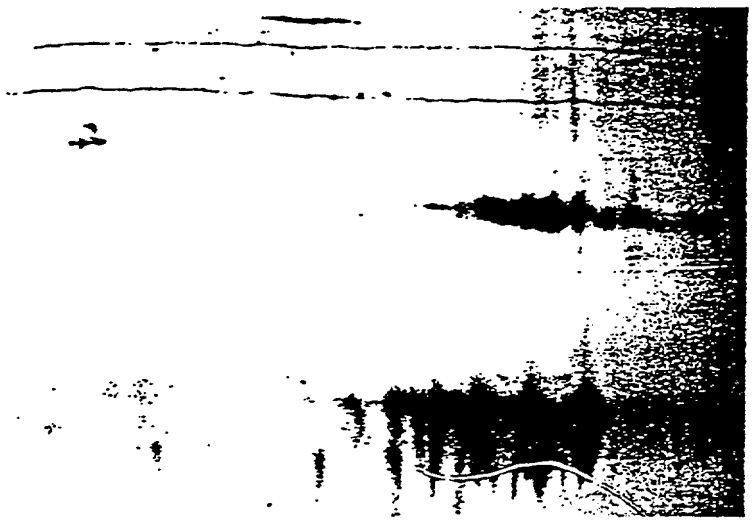


Fig. 19A

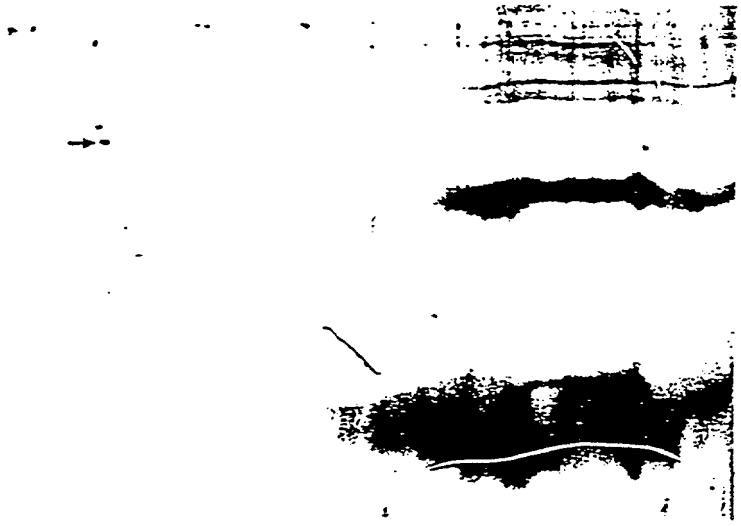


Fig. 19B

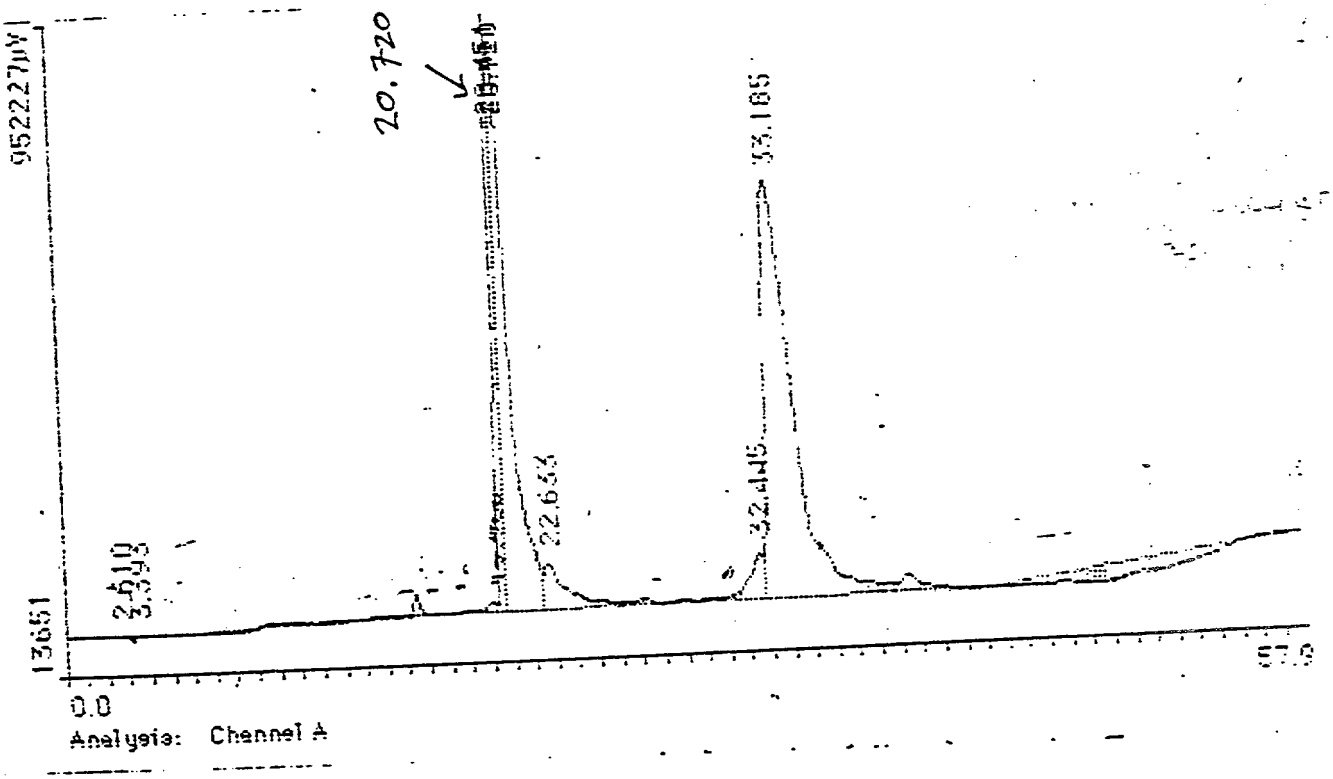

952227μW
20.720
33.185
22.643
32.445
3.393
13651
0.0
Analysis: Channel A

Figure 21

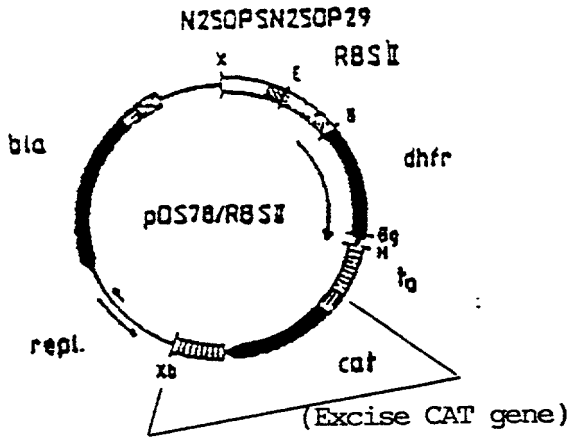


FIG. 22A

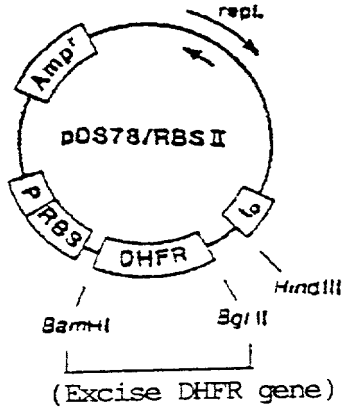


FIG. 22B

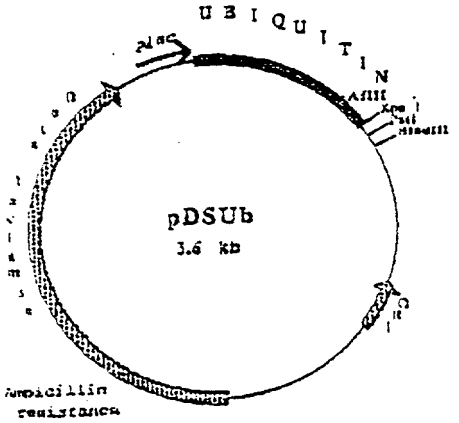


FIG. 22C

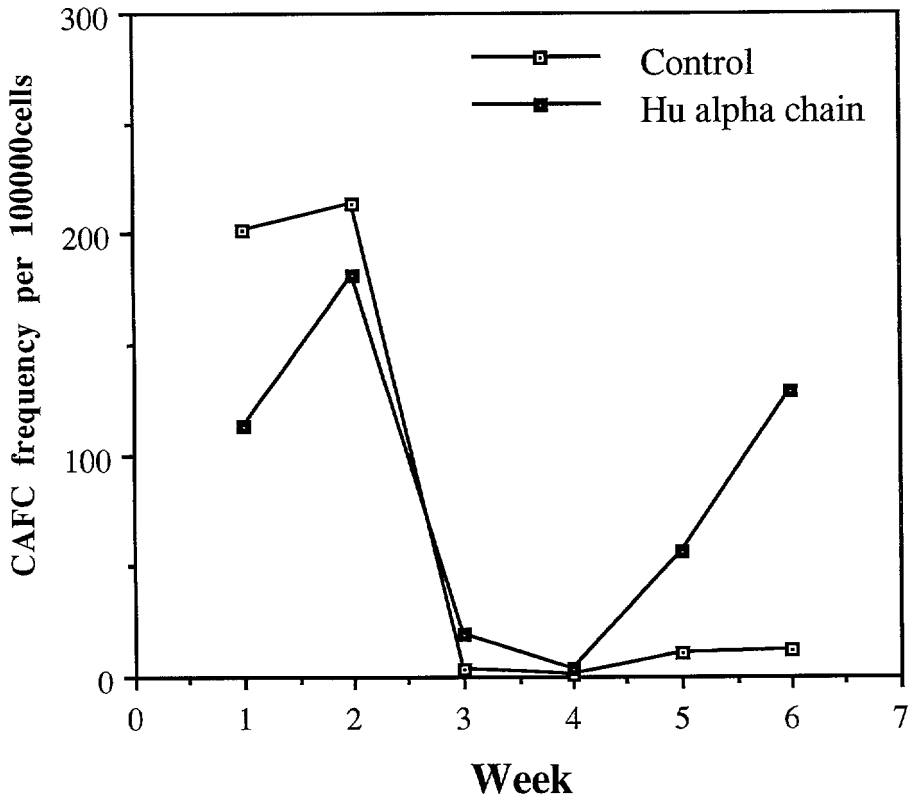

300
200
100
0
0
1
2
3
4
5
6
7
CAFC frequency per 100000cells
Week
Control
Hu alpha chain

Fig. 23